U.S. Department of Energy • Office of Fossil Energy
National Energy Technology Laboratory

Institutional Plan

FY 2003 - 2007

NETL

Disclaimer

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1 Introduction

1.1 Laboratory Director's Statement

At the National Energy Technology Laboratory (NETL), our primary mission is to help ensure that the United States has a reliable, affordable, diverse, and environmentally sound energy supply. We do this by developing advanced technologies to produce, transport, and use our fossil energy resources. Our research and technology development programs are implemented on behalf of the DOE's Office of Fossil Energy and cover the breadth of fossil energy resources—coal, oil, and natural gas. Our work helps guarantee every American a continued high quality of life, driven by an economic engine fueled by secure, domestic fossil fuels.

We also support other parts of DOE. For the past decade, we have developed environmental remediation technologies for DOE's Office of Environmental Management (EM). We also provide support for DOE's Office of Energy Efficiency and Renewable Energy (EE), particularly for technologies with a synergism to our fossil energy portfolio.

In addition to conducting leading-edge research on site, we partner with private industry, universities, and other governmental organizations on nearly 1,300 research activities at sites located in all 50 states and 10 foreign countries. Our projects—with a total award value of about $8 billion, and a private sector cost-share investment of over $2 billion—offer technology-based solutions to problems of energy supply, production, and use, and environmental quality.

We take our charge—stewardship of the trust and the funds of American taxpayers—seriously. We are committed to delivering technologies that will:

- Allow the deployment of Vision 21 energy plants that are fuel-flexible, capable of multi-product output, have near-zero emissions of criteria pollutants, and have efficiencies over 60 percent with coal and 75 percent with natural gas.

- Provide Vision 21 plants with the option for near-zero carbon emissions by developing low-cost, well-validated approaches to capture, transport, and sequester carbon dioxide.

- Expand the 2003 domestic oil and gas economically recoverable resource base by 2 billion barrels of oil and 75 trillion cubic feet (TCF) of natural gas and ensure the safe, reliable, and secure delivery of oil and gas to the end user with minimal environmental impact.

- Accelerate the closure of DOE's former nuclear sites by providing alternatives to high-risk, high-cost baseline technologies.

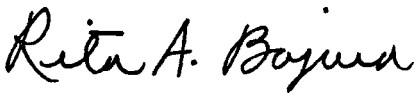
In addition, we will provide:

- Sound technical information and energy policy analyses in support of the NETL's RD&D projects.

- World-class science and technology in our six onsite research Focus Areas: Carbon Sequestration Science, Computational Energy Science, Clean Fuels, Environmental Research, Gas Energy System Dynamics, and Vision 21 Advanced Power Systems.

- Quality services to support DOE's policy decisions, best management practices, acquisition planning, and cost estimating.

We are here to make a difference!



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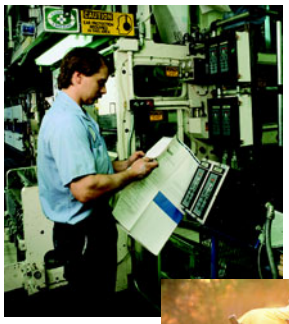
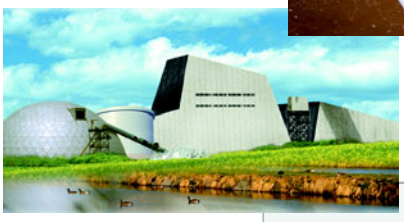




On average, each person in the United States spends about $2,000 annually for energy

1.2 Executive Summary

The NETL works to resolve the environmental, supply, and reliability constraints associated with producing and using fossil fuels. To do this we focus on four key research areas in fossil energy:

- ***Electric Power***—coal production, power delivery, and power generation.
- ***Natural Gas***—exploration and production, pipeline and storage infrastructure, and power generation.
- ***Clean Liquid Fuels***—exploration and production, refining and delivery, and transportation.
- ***Technology Policy Support for Energy Issues***.

We also develop and deploy environmental tech-nologies that reduce the cost and risk of remediating the environmental damage resulting from decades of activity in the Department of Energy's weapons complex.

Fossil fuels (coal, oil, and natural gas) provide 85 percent of our energy in the United States. These fuels are a key ingredient for domestic economic growth and competitiveness. Because of the degree to which fossil fuels affect the lives of every American, the Federal Government has an important role in funding and conducting energy research in pursuit of benefits that market forces cannot deliver. Federal energy research is focused on (1) human health—delivering the means to improve air emissions, (2) the environment—reducing water and land impacts, (3) economic well being—providing the innovations that keep energy costs affordable, (4) safety—improving the reliability of energy technologies, and (5) national security—increasing our independence from foreign fuels.

We make advances in technology using the expertise of researchers working in our onsite laboratories as well as in the laboratories and facilities of private sector and academic institutions throughout the United States and other countries. Onsite science and technology research at the NETL focuses on developing environmental control technologies for the existing fleet of coal plants, natural-gas-fueled power systems, clean fuels for high-efficiency transportation systems, carbon sequestration technology for large stationary sources of carbon dioxide, and virtual demonstrations of the energy plants of the future using computational sciences.

Fuel provides mobility

With our reliance on energy so completely intertwined with our daily lives, the public benefits of the Laboratory's work touch all of us. The benefits of our work are demonstrated by the outcomes of the Laboratory's research programs:

- ***Technology***—providing acceptable, affordable, and available energy systems to meet the challenges facing the United States in the mid to long term.
- ***Policy Support***—positively impacting the development of sound energy policies by being a reliable and trusted source of information about the performance and cost of fossil fuel-based technologies.
- ***U.S. Competitiveness***—maintaining the technological competitiveness of the U.S. energy industry.
- ***Stability***—appropriately transferring technology to developing countries to improve geopolitical stability and providing the means to reduce emissions of criteria pollutants and greenhouse gases.
- ***Competent Workforce***—providing a highly skilled energy workforce through university research programs.
- ***Regional Benefits***—contributing to regional economic development through partnerships and regional research consortia.

The National Energy Policy, published in May 2001, underscores the importance of energy and the need for continued attention to the energy challenges facing the United States. That document states, "America's energy challenge begins with our expanding economy, growing population, and rising standard of living. Our prosperity and way of life are sustained by energy use." The National Energy Policy describes the principal energy challenges facing the Nation as "… promoting energy conservation, repairing and modernizing our energy infrastructure, and increasing our energy supplies in ways that protect and improve the environment. Meeting each of these challenges is critical to expanding our economy, meeting the needs of a growing population, and raising the American standard of living."

Energy is needed to produce food and deliver clean water to our homes

The NETL is committed to making a significant contribution to successfully meeting these challenges.

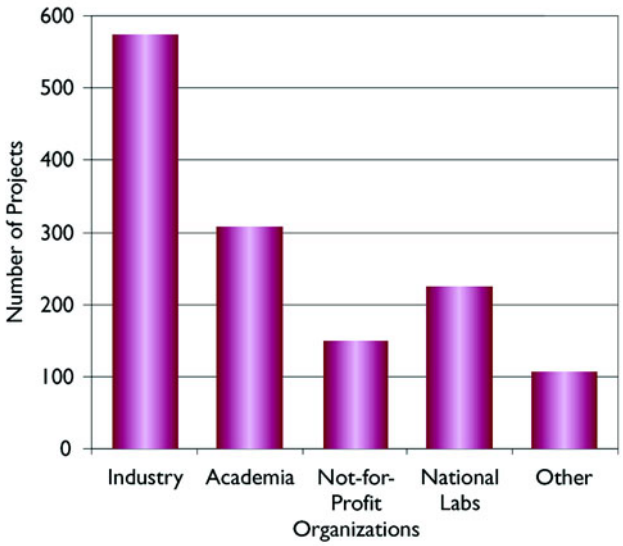
2 Laboratory Overview

2.1 Laboratory Description

The National Energy Technology Laboratory (NETL) is a multi-purpose laboratory, owned and operated by the U.S. Department of Energy (DOE). We conduct and implement science and technology development programs for the Department in energy and energy-related environmental systems. Our organization, formerly the Federal Energy Technology Center, was established in 1996 through consolidation of Energy Technology Centers at Morgantown, WV, and at Pittsburgh, PA. In December 1999, we were designated the Department's 15th national laboratory. In October 2000, the National Petroleum Technology Office (NPTO) in Tulsa was assimilated into the NETL. In 2001, we opened an office in Fairbanks, Alaska. The DOE Assistant Secretary for Fossil Energy is the NETL's Lead Program Secretarial Officer.

Our research and development (R&D) activities are conducted on- and offsite through partnerships, cooperative research and development agreements (CRADAs), financial assistance, and contractual arrangements. The nearly 1,300 research, development, and demonstration (RD&D) projects in the NETL's portfolio are conducted in partnership with industry, universities, other national and Federal laboratories, private research organizations, and other Federal and State agencies. Our hallmark is the ability to assemble industrial, academic, and governmental resources to create commercially viable solutions to energy and environmental problems.

The NETL is the only national laboratory within the DOE complex that is Government-owned and -operated (GOGO). Our Federal employees staff research, product management, project management, and higher level administrative functions. The NETL has the authorities of a DOE operations office integrated with the implementing functions typically conducted by Management and Operating (M&O) contractors.



Projects by Partner Group

Nearly one-half of the NETL's R&D activities are carried out by private sector organizations. This emphasis on the private sector is essential to our mission. To be successful, the advanced technologies emerging from the NETL's research programs must be commercialized by the private sector. Therefore, intellectual and cost-sharing involvement by the private sector early in the RD&D process provides an intrinsic technology transfer mechanism that accelerates the deployment of new technologies. Private sector involvement brings about a better understanding of end-user needs, and helps assure that the new technologies will gain rapid acceptance in the marketplace. We believe that public-private RD&D partnerships can most rapidly deliver the cost, reliability, and environmental benefits offered by new technologies. Our status as Federal employees facilitates these partnerships. We have no interest in competing with our partners to commercialize technology and are, therefore, well positioned to successfully implement RD&D programs.

Over 590 federal employees work at the NETL. The staff also includes over 550 site support contractor employees. Major site support contractors include Concurrent Technologies Corporation; D.N. American; EG&G Technical Services of WV (EG&G); Energy and Environmental Solutions LLC (EG&G/Science Applications International Corporation); Parsons; RMC, Inc.; and TRW, Inc. These contractors have subcontractual arrangements with more than 50 additional organizations, many of which are small and minority businesses. KRay, PACE TEC, and TJR provide custodial and security services at the Pittsburgh and Morgantown sites.

The American Federation of Government Employees (AFGE) Locals 1916 and 1995 represent the NETL's Federal bargaining unit employees. A Labor Management Partnership Council works to identify problems and develop solutions that enhance quality and productivity, improve services to stakeholders, and promote a family-friendly workplace. Three unions represent employees in our site support contractor workforce: United Mine Workers of America (Locals 1914 and 1717); International Union of Operating Engineers Local 95; and Security, Police, and Fire Professionals of America (Local 502). Management and Labor are committed to the NETL's success and work together to achieve that goal.

2.2 Our Mission and Vision

Our primary mission is resolving the environmental, supply, and reliability constraints of producing and using fossil resources. We do this through our work for DOE's Office of Fossil Energy (FE). We are responsible for implementing coal, oil, and gas programs for FE. The NETL and its predecessor organizations have conducted and implemented research on energy technologies for the past 91 years.

We support other parts of the Department. We support DOE's Office of Energy Efficiency and Renewable Energy (EE) by developing new energy technologies that complement work underway in the FE program. We also support DOE's Office of Environmental Management (EM) by developing technologies and by formulating and reviewing processes and systems that will reduce the cost and risk of remediating DOE's weapons complex. The NETL has supported the EM organization for the past 11 years.

We also provide services for other Federal agencies including the Environmental Protection Agency (EPA); the National Park Service; the Department of Defense (DOD); the Department of State, Agency for International Development; and the Department of Veterans Affairs. We work with various State groups, including the California Energy Commission, the Ohio Coal Development Office, the Interstate Oil and Gas Compact Commission, and the Illinois and Pennsylvania Coal Caucuses. Our portfolio of projects also includes activities with several Native American organizations.

Our vision is to be the preferred provider of energy technology and policy options that benefit the public.

The NETL will measure attainment of its vision by:

- ***Investment Results***—Government Performance and Results Act (GPRA) performance and OMB R&D investment scoring (See section 2.4)
- ***Customer Satisfaction***—Funding received and use of our information products
- ***Organizational Effectiveness***—Strategic focus, contracted projects, onsite R&D, and financial management
- ***Human and Physical Resources***—Safety, employee investment, infrastructure investment, and annual assessments

2.3 Key Activities and Core Competency Areas

To accomplish its mission and vision, the NETL performs the following key activities:

- Shape, fund, and manage extramural (external) RD&D programs for FE.
- Conduct onsite research and technology development, primarily for coal and natural gas technologies. Onsite laboratory facilities are located at the NETL's Morgantown and Pittsburgh sites.
- Assess energy systems and conduct other studies to support energy policy development.
- Provide procurement and project management support for several programs within EE.
- Coordinate energy research and development activities with other Federal agencies.
- Support best business practices within the Department of Energy.

The NETL has developed a broad set of skills needed to accomplish our mission. Our primary technical and managerial skills are the following:

- Expertise in the science and engineering of technologies to produce and use coal, oil, and natural gas.
- Proven capability to work effectively with the private sector to structure and implement cost-shared energy and environmental RD&D programs.
- World-class knowledge of the chemistry of solid, liquid, and gaseous fuels and their transformations.
- Ability to foster the development of innovative technologies to remediate radiologically contaminated sites.

Technical and Management Skills

Expertise in the science and engineering of technologies to produce and use coal, oil, and natural gas	Ability to work effectively with the private sector to structure and implement RD&D programs	World-class knowledge of the chemistry of solid, liquid, and gaseous fuels and their transformations	Ability to foster the development of innovative technology to remediate radiologically contaminated sites

Core Competency Areas

Science	Engineering	Policy Analysis	Administration
• Combustion science • Fuel chemistry • Surface science • Adsorption phenomena • Chemical kinetics • Biology • Environmental hydrology • Geology • Geophysics • Multiphase Flow	• Fluid flow • Mass transport • Engineering of combustion devices • Fluidization • Surface and ground water characterization • Mathematical simulation • Cost estimating	• Energy system assessment • Fossil energy resource and emissions assessment • International collaboration and project development • Understanding of the market and economic forces that influence the production and utilization of fossil energy	• Project management • Financial management • Procurement • Legal • Intellectual property • Environmental impact studies • Information Technology

2.4 Performance Measurement

Driven by the Government Performance and Results Acts of 1993 (GPRA) and aspects of the President's Management Agenda that focus on the integration of performance and budget, performance measurement in the Federal Government is undergoing changes that herald continually increasing rigor. In response, the NETL has strived to be "ahead of the curve," focusing on assignments that tie to a national agenda, and exercising diligence in developing performance measures that demonstrate that current-year outputs will lead to future-year outcomes.

NETL's Role in DOE's Strategic Objectives

We measure our performance in attaining our vision using a GPRA-driven tool called Joule. The principal activities at the NETL support DOE's Energy Resources Business Line. This Business Line currently has nine Strategic Objectives, major accomplishments measurable and achievable within 15 years or more. Two of the nine apply to the NETL.

- **The Coal and Power Strategic Objective (ER4).** *By 2015, develop the technology to allow the deployment of zero-emission plants that are fuel-flexible and capable of multi-product output, with efficiencies over 60 percent with coal and 75 percent with natural gas, and develop the compatible companion technologies that allow low-cost carbon sequestration.*

- **The Oil and Natural Gas Strategic Objective (ER5).** *By 2015, develop technologies to expand the 2003 domestic oil and gas economically recoverable resource base by 2 billion barrels of oil and 75 trillion cubic feet (TCF) of natural gas and ensure the safe, reliable, and secure delivery of oil and gas to the end user with minimal environmental impact.*

These two Strategic Objectives will drive the NETL's work in FY 2003.

Program Strategic Performance Goals (PSPGs) represent intermediate goals. They are statements of intended results during the next 5 to 8 years toward attaining the Strategic Objective. In general, a PSPG represents work that has a common theme. We have written PSPGs for each of our "Project Portfolios," a programmatic ensemble that usually, but not always, corresponds to our Product Lines. PSPGs are not activities or processes.

ER 4 focuses on the coal-related aspects of DOE's fossil energy program. The PSPGs against which the NETL's performance will be measured are:

- *By 2005, complete initial demonstration tests of technologies with potential to reduce mercury by 50-70 percent; NO_x to less than 0.15 lb per million Btu at three-fourths the cost of SCR; $PM_{2.5}$ by 99.99 percent; and acid gases by 95 percent; by 2010, test technologies for advanced cooling, mercury reduction by 90 percent, and 66 percent increase in byproducts utilization. (*ER 4-1)

- *By 2008, develop advanced power systems capable of achieving 50 percent thermal efficiency at a capital cost of $1,000/kW or less for a coal-based plant*. (ER 4-2)

- *By 2007 demonstrate at a pilot-plant scale, technologies to reduce the cost of carbon dioxide separation and capture from new coal-based power systems by 75 percent compared to current (circa 2000) systems. By 2012, develop technologies to separate, capture, transport, and sequester carbon, using either direct or indirect systems, that result in less than a 10 percent increase in the cost of new energy generation.* (ER 4-3)

- *By 2010 introduce prototypes of (a) modular fuel cells with 90 percent cost reduction ($400/kW), with 40 to 50 percent efficiency; and (b) fuel-cell, turbine hybrids with 60 to 70 percent efficiency adaptable for coal gas*. (ER 4-4)

- *By 2010, complete development of modules capable of coproducing clean fuels (liquids or hydrogen) from coal at $30/barrel crude oil equivalent (no incentives or tax credits) when integrated with advanced coal power systems.* (ER 4-5)

- *Demonstrate advanced coal-based power generation technologies that improve efficiency, environmental and economic performance; coproduce heat, fuels, chemicals or other useful byproducts; and provide a deployment-ready suite of advanced technologies that can produce substantial near-, mid-, and long-range economic and environmental public benefits.* (ER 4-6)

- *Sustain U.S. preeminence in fossil fuel technology by supporting development of material, computational-method, and control-system knowledge needed to bridge gaps between science and advanced engineering and allow development, by 2010, of enabling technologies that support the goals of Vision 21 power systems.* (ER 4-7)

ER 5 focuses on the oil- and gas-related components of DOE's fossil energy program. The PSPGs against which the NETL's performance will be measured are:

- *By 2008, develop and field-test a suite of technologies in the areas of natural gas exploration and production with the potential to increase the economically recoverable gas resource by 12 Tcf from existing fields and unconventional reservoirs.* (ER 5-1)

- *By 2010, develop and field-test a suite of methane hydrate technologies for increasing the safety of offshore oil and gas operations in the Gulf of Mexico, thoroughly characterize resource deposits in Alaska, and comprehensively study global environment implications.* (ER 5-2)

- *By 2008, develop and field-test a suite of technologies in the area of natural gas infrastructure and storage to meet increasing demand (based on DOE's Annual Energy Outlook 2002) in a safe, reliable, and secure manner as prescribed by the National Energy Policy.* (ER 5-3)

- *By 2008, develop and field-test a suite of technologies in oil exploration and production with the potential to increase the hydrocarbon resource base by 0.6 billion barrels of oil and 0.1 Tcf of natural gas from existing and frontier resources.* (ER 5-4)

- *By 2008, develop and demonstrate technologies in refining, delivery, and oil and gas environmental management with potential to reduce costs of environmental protection in field operations and refining by $1.6 billion with some production increases while improving the Nation's air, water, and soil quality.* (ER 5-5)

- *By 2008 (assuming the program is funded), complete development of technologies in fuels chemistry/oil technology, alternate feedstocks and hydrogen fuels to provide significantly lower cost syngas and hydrogen from natural gas (25 percent less costly) with the potential to make 7 million more barrels of oil refineable, and reduce other costs by $1.9 billion, to produce a variety of end-use fuel products, and to improve the quality of the Nation's transportation fuels.* (ER 5-6)

All 13 of the PSPGs have a series of targets. They are developed to be "presidential, specific, quantified, meaningful, challenging, concise, written for taxpayers, and auditable." Targets, like PSPGs, are not activities or processes.

Each of the targets has a set of quarterly milestones—output-oriented activities that demonstrate steps forward in achieving the targets. This series of quarterly milestones is the heart of the input to the Joule system.

Using a commercial performance-measurement software package, pbViews, DOE's Office of the Chief Financial Officer will track the NETL's progress on a quarterly basis. The system will have Performance Indicators to demonstrate whether attainment of the quarterly milestones is leading to achieving the annual targets, and a separate Performance Indicator to show whether reaching our annual targets is leading to accomplishing our PSPGs.

NETL High-level Metrics

The NETL measures its performance using a set of "High-level Metrics." For FY 2003, the NETL has developed a set of measures based on the Malcolm Baldrige criteria. Consistent with the four components of the Baldrige Business Results criterion, the NETL has established a "dashboard"—gauges to be tracked by management. These four gauges are:

- ***Customer Satisfaction***—The NETL will measure its ability to satisfy customers by the level of funding provided and by the use of its information products.

- ***Investment Results***—This gauge will focus on the OMB Scorecard results (scores related to the OMB Investment Criteria) and the NETL's performance against its GPRA targets.

- ***Human and Physical Resources***—This gauge measures our performance in investing in the development and improvement of our employees and physical infrastructure. It will have four indices—Safety, Employees, Infrastructure, as well as Assessments and Surveys.

- ***Organizational Effectiveness***—This gauge will roll up the NETL's performance in the areas of Strategic Focus, Project Management and Acquisition, Science and Technology (onsite R&D), and Financial Management.

All of the subgauges consist of a series of measures, many of which represent stretch goals for the organization. On a quarterly basis, a presentation on the status of all metrics is made to the NETL's Executive Board. In those cases where the status does not appear to be on track, management action is taken to ensure that performance expectations are realized.

2.5 Program Areas

The DOE Strategic Plan identifies four major Business Lines (Energy Resources, National Nuclear Security, Environmental Quality, and Science) that are the focus of DOE's activities. The NETL has five business sectors that support the Department's Business Lines. This section describes the NETL's role in these Business Lines and provides an introduction to more detailed descriptions of the five NETL business sectors to be found in chapters 3 to 7 of this plan.

Energy Resources

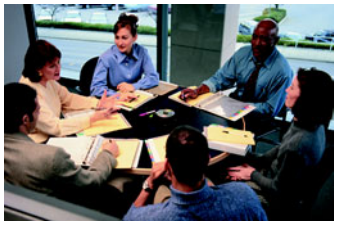
The Energy Resources Business Line of DOE is the NETL's major mission area. We are a key resource in the development of the science and technology needed to support DOE's mission of fostering "a secure and reliable energy system that is environmentally and economically sustainable." Most of this activity is conducted for the Office of Fossil Energy (FE).

Four of the NETL's business sectors support the Department's Energy Resources Business Line:

1. ***Electric Power, Clean Fuels, and Hydrogen Using Coal***—This NETL business sector focuses on developing low-cost environmental control technologies for the existing fleet of power plants, ultrahigh-efficiency technologies for the next generation of power and fuels production plants, and carbon sequestration technologies to address greenhouse gas concerns. This activity also includes the NETL's work in water and mining. The program areas that constitute this business sector are described in more detail in chapter 3.

2. ***Strategic Center for Natural Gas***—The SCNG pursues advances in exploration and production, infrastructure reliability, and end-use technologies, including fuel cells for distributed power and gas turbines systems for large industrial and utility applications. This business sector is described in more detail in chapter 4.

3. ***Petroleum Technology***—The NETL's oil business sector focuses on (1) enhancing the efficiency of domestic oil exploration, recovery, and processing while improving environmental quality, and (2) the development of approaches to convert natural gas (nearer term) and coal (longer term) into fuel for transportation and other end-use sectors. This business sector is described in more detail in chapter 5.



4. ***Energy Policy Analysis***—Questions of availability, affordability, and acceptability of energy resources require sound policy development. This can only be accomplished if adequate technical information is available and understood. This business sector provides analyses and knowledge products to actively support development of energy policies. Chapter 7 of this plan describes in more detail the three program areas that constitute this business sector.

Environmental Quality and National Nuclear Security

Environmental Technology and Business Excellence. This fifth NETL business sector supports both the Environmental Quality and the National Nuclear Security Business Lines of DOE. The NETL supports the cleanup of DOE's weapons complex by implementing extramural technology development programs for the DOE Office of Environmental Management (EM). The NETL's Center for Acquisition and Business Excellence (CABE) provides technical and business services for EM and other parts of DOE. Our role in DOE's National Nuclear Security Business Line is to foster development of partnerships and programs in areas where there is a synergism between the NETL's energy activities and the National Nuclear Security Administration's needs. This business sector is described in more detail in chapter 6.

Science and Technology

The NETL has several onsite science and technology development activities that, in addition to supporting DOE's Energy Resources Business Line, also contribute to DOE's Science Business Line.

The NETL's role in DOE's Science Business Line is to:

- Pursue scientific advances as well as technology development.
- Seek opportunities to utilize scientific advancements made by DOE laboratories to support the NETL's energy and environmental mission areas.
- Develop partnerships between industrial organizations that are performing applied R&D and DOE laboratories that conduct fundamental research in related areas.

The Laboratory's onsite science and technology development activities include the following:

- ***Carbon Sequestration Science Focus Area***—Provides scientific bases for engineered carbon sequestration options for large stationary sources of carbon dioxide. The desired outcome of this activity is economic and environmentally sound sequestration options. The Focus Area conducts exploratory studies and develops models to assess the performance, safety, and cost of engineered carbon sequestration approaches.
- ***Computational Energy Science Focus Area***—Uses advanced computer simulation techniques to facilitate the development of cleaner and more efficient energy devices and plants. Work centers on developing a set of rigorous but flexible computational tools that will allow more rapid and efficient scale-up of new subsystems, devices, and components. When fully developed, these tools will reduce the need for large and expensive demonstration-scale testing and fundamentally alter the process by which advanced energy plant concepts are developed.
- ***Gas Energy System Dynamics Focus Area***—Addresses scientific issues in transient and unsteady operation of gas energy systems. Activities will lead to improved understanding of the operating characteristics and the dynamic phenomena that underlie successful development of the next generation of gas turbines, fuel cells, coupled turbine and fuel-cell systems, and reciprocating engines, and will lay the foundation for new gas utilization technologies.
- ***Clean Fuels Focus Area***—Develops enabling science for the production of clean and affordable fossil-based fuels for high-efficiency transportation systems. Laboratory personnel conduct fundamental and applied studies in areas ranging from computational chemistry to systems analyses for fuel formulation for advanced engines.
- ***Environmental Research Focus Area***—Develops technology to reduce contaminants, such as mercury and fine particles, from power plant emissions. This Focus Area is investigating practical and environmentally benign uses for combustion byproducts such as fly ash. Technologies and analytical tools are also being developed to improve water quality in watersheds.
- ***Vision 21 Research Focus Area***—Investigates the supporting science for high-efficiency energy plants of the future, ones that incorporate pollution control as an integral part of the design. Research areas include advanced materials testing, gas stream pollutant removal, sorbent development, hot particulate removal, and virtual simulation.

NETL PROGRAM AREAS

Energy Resources

- **Electric Power Using Coal**
  - Environmental Technologies for Current Fleet of Power Plants
  - Efficiency Improvements for Next-Generation Plants
  - Clean Fuels from Coal
  - Mining/Water: Addressing Energy Supply Issues
  - Carbon Sequestration: Important Options to Address Climate Change

- **Strategic Center for Natural Gas**
  - Gas Exploration and Production
  - Distributed Generation
  - Gas Infrastructure Reliability
  - Advanced Turbines and Engines

- **Petroleum Technology**
  - Petroleum Exploration and Production
  - Environmental Solutions
  - Petroleum Fuels

- **Energy Policy Analysis**
  - Fossil Fuel Issues
  - Climate Change Support
  - International Projects: A Critical Element in Addressing Climate Change

Environmental Quality and National Nuclear Security

- Environmental Management: Reducing Cost and Risk of Remediating DOE's Weapons Complex

- Center for Acquisition and Business Excellence (CABE): Technical and Business Services for DOE

- Commercial Nuclear Utility Decommissioning

Science and Technology—Onsite Activities

- **Carbon Sequestration**
- **Computational Energy Science**
- **Clean Fuels**
- **Gas Energy System Dynamics**
- **Environmental Research**
- **Vision 21 Research**

3 Electric Power, Clean Fuels, and Hydrogen Using Coal

Coal is a critically important national treasure; it is the Nation's most abundant and lowest cost fuel. According to the EIA Annual Energy Outlook 2002, 90 percent of coal mined in the United States is used to produce electricity. Coal provides 52 percent of United States electricity helping to make United States electricity affordable and reliable. For the foreseeable future, no alternative power generation technology is expected to replace this national resource. Nearly 31 gigawatts of new coal-fired capacity is projected to be added to the United States grid by 2020, accounting for almost 9 percent of all capacity expansion. This along with higher load factors will result in an increase in coal usage of almost 290 million short tons (965 to 1,254) per year.

Coal is the primary fuel for electricity generation in the United States

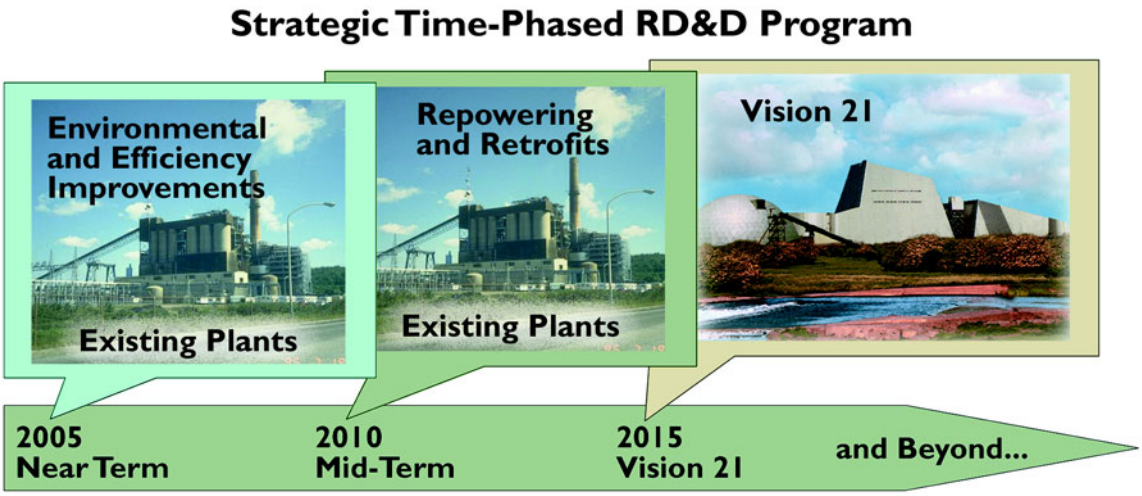
Internationally, the demand for electricity is projected to nearly double by 2020, with the greatest increase in developing countries. Because many developing countries have large indigenous coal supplies, much of this increase will be fueled by coal.

The United States imports approximately 11 million barrels per day of petroleum crude and finished products (55 percent of consumption). By 2020, imports are projected to rise to 17.5 million barrels per day of crude and refined products (67 percent of consumption). At present, the United States imports about 2.2 million barrels per day of oil from the Middle East. Imports from this source are expected to increase to over 5 million barrels per day by 2020. While U.S. imports from the Middle East are relatively modest, oil is a global commodity. The Middle East contains 75 percent of global reserves and will provide the bulk of the world's exportable petroleum crude. Coal-derived fuels can be an important part of a strategy to diversify and expand our domestic fuel resource base, and can help to limit our reliance on imported oil.

Traditional coal use presents a number of regional and global environmental challenges. The principles of "industrial ecology" can help the Nation address these environmental challenges and enable coal to continue to provide the United States with affordable electricity. The principles of industrial ecology optimize systems by minimizing the impacts on energy, environmental, and material resources; maximizing thermal, material, and human efficiencies; and minimizing waste (including emissions). Thus, environmental stewardship is designed into systems from the outset. Systems such as coal-fired power generation are monitored and managed throughout their life cycle.

Reliable, high-quality electricity is fundamental to a stable economy. The U.S. electricity generation system has become more susceptible to upsets. Uncertainties in the environmental and regulatory regime have limited the number of new coal plants constructed. Electricity supply has not kept up with demand. Generation and transmission reserve margins have dropped from about 35 percent in the 1980s to less than 15 percent in some parts of the country today. Electricity prices have become more volatile because of supply shortages and because of the price volatility of natural gas purchased for power generation. The average age of the power plant fleet is increasing. As a result, older power plants are offline more frequently because of unscheduled outages for maintenance.

The coal RD&D programs responds to these issues through mid- and longer term RD&D activities that address everything from technologies for refurbishment and cost-effective environmental control of existing power plants to fuel- and product-flexible technologies with the promise of zero emissions for new power plants. Success in these programs will enable the Nation to enjoy the benefits of secure, affordable, and clean energy systems fueled by coal in the mid-to-longer term.



3.1 Existing Fleet Technologies

The existing fleet of coal-fired power plants is faced with meeting increasingly stringent environmental regulations. Air emissions are a primary focus. The Clean Air Act, particularly the 1990 amendments, raised national expectations relative to the environmental performance of coal-based power systems. Contaminants of concern include emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), hazardous air pollutants (especially mercury), and fine particulate matter ($PM_{2.5}$). Carbon dioxide, a greenhouse gas, is also of concern because of its potential to contribute to global climate change.

Much progress has been made in reducing emissions from coal plants. However, the anticipation of more stringent regulations in the near term, along with a longer term goal to develop "near-zero-emission" coal plants, drive the need for RD&D for advanced coal power-generation technologies. The NETL is developing technologies that enable reductions in allowable emissions of NO_x, hazardous air pollutants (especially mercury), $PM_{2.5}$, and acid gases. The Environmental Protection Agency (EPA) is pursuing or considering reductions of these emissions to deal with ambient air quality (ground-level ozone, $PM_{2.5}$, and air toxics), visibility impairment ($PM_{2.5}$) and regional haze, and the health of terrestrial and aquatic ecosystems (mercury, acid rain, and eutrophication).

In the past, environmental regulations have been issued incrementally—generally one pollutant was regulated at a time. This approach has proven to be costly to the electric power industry and ultimately to the ratepayers. The Administration's National Energy Policy recommended a new approach that could achieve equivalent reductions in pollutants at much lower cost. To implement this recommendation, the Administration proposed a multi-pollutant approach called the Clear Skies Initiative. The Administration's Clear Skies Initiative proposes further reductions of SO_2 and NO_x emissions and would cap mercury emissions. By coupling groups of pollutants into a single regulation, it will be possible to use control strategies that deal with multiple pollutants and their interactions as a group.

With the possibility of further restrictions on air emissions, attention is being focused on the use and disposal of byproducts from coal utilization and from the cleanup technologies that reduce air emissions at power plants. Flue gas desulfurization (FGD) byproducts are being used to produce saleable gypsum for wallboard production, and ash collected by electrostatic precipitators is valued in the marketplace as an additive for making strong but lightweight concrete. When regulations are imposed on power plants to control mercury, the state-of-the-art technology (carbon injection) may create problems for the sale of ash from power plants. Of particular concern is the ultimate fate of mercury and other toxic substances once they are captured from the power plant flue gas.

Water is also an emerging issue for power plants. The EPA is developing regulations to implement a section of the Clean Water Act that deals with cooling water intake structures. The New Source Review rule may have a role in shaping similar rules for existing facilities. Under the proposed rule, existing facilities may be required to install closed-cycle cooling systems, presumably wet cooling towers, to reduce water consumption. Furthermore, the environmental community and several States have supported the use of dry-cooling technology to eliminate or significantly reduce the need for cooling water. Because over 50 percent of existing coal-fired power plants employ once-through cooling systems, an EPA decision to require the existing fleet to install dry- or wet-cooling tower systems could significantly reduce the thermal efficiency of these plants. Power losses from the decreased efficiencies would need to be supplied by other power-generation systems; thus, there is a strong likelihood that greenhouse gases and other atmospheric emissions would increase.

The coal RD&D program addresses the needs of the existing coal-based power generation infrastructure. Advanced technologies are being developed to enable these plants to meet performance, reliability, environmental, and cost goals. In turn, this enables the Nation to enjoy the reliability and cost benefits of maintaining coal as part of our power generation portfolio.

Program Status

Over the past 15 years, the Clean Coal Demonstration program and other initiatives directed at near- and mid-term needs have successfully demonstrated technologies that:

- Increase efficiency and reduce emissions from coal-fired power plants and industrial facilities.
- Expand the number of options, such as fluidized-bed boilers and gasifiers, available for the clean use of coal.
- Produce coal-based fuels that burn cleaner and help reduce emissions.

The Wabash River IGCC plant is the largest single-train coal-fired and petroleum coke-fired gasification plant in the world. It won the 1996 Power Plant of the Year Award

Many of the technologies that have been demonstrated under these programs are now in commercial use. Advanced versions of others are being further developed in the R&D program.

"Advances in clean coal technology allow us to use America's abundant coal reserves more efficiently and, at the same time, protect the quality of our environment. America's clean coal technology program will be an important part of the Administration's comprehensive national energy plan."

Spencer Abraham
Secretary of Energy

To address the numerous environmental challenges noted above, the NETL is carrying out a focused, highly leveraged research program in the areas of $PM_{2.5}$, NO_x, mercury and other air toxics, acid gases, coal utilization byproducts (CUB), and water resources. The success of the NETL program is linked to partnerships with industry, Federal, State, and local agencies, non-government organizations, and the academic and research communities.

As part of the research program, the NETL develops high-quality scientific information on environmental issues affecting the production and use of fossil fuels. The NETL plays an important role in the interagency review process by providing this information. NETL-generated information has been used in a number of policy and regulatory initiatives including:

- Mercury Report to Congress.
- Hazardous Air Pollutants Report to Congress.
- Cost of Mercury Control.
- EPA Mercury Information Collection Request.
- Proposals to Lower Toxic Release Inventory Reporting Thresholds for Mercury, Lead, and Dioxin.
- Draft Cooling Water Intake Structure Requirements.
- Draft Arsenic Drinking Water Standards.
- Regulation of CUBs.
- Draft EPA Air-Water Interface Work Plan.
- Multi-pollutant Control Strategies/Scenarios.

Sampling flue gas for mercury at the NETL 500-lb/hr coal combustion test facility

NETL researchers in the Environmental Research Focus Area conduct laboratory- and bench-scale evaluations of the cost and effectiveness of activated carbon and novel sorbents for controlling mercury emissions; and they conduct extensive leaching tests to evaluate the environmental safety of CUBs.

DOE has established a set of national priorities that include the goal to promote secure, competitive, and environmentally responsible energy systems that serve the needs of the public. The NETL's Innovations for Existing Plants program promotes the development of advanced environmental control technologies for reducing environmental releases (air, water, and solids) and the safe use and disposal of CUBs from coal-based power systems.

In response to the 1997 $PM_{2.5}$ National Ambient Air Quality Standards and related concerns about regional haze, the NETL initiated an extensive program to better understand the interactions of coal-fired boiler emissions and other man-made emissions and their impacts on ambient air quality. The program includes air-quality monitoring, source-emissions characterization, and control technology development.

One goal of this program is to develop systems capable of controlling NO_x emissions to levels required in State Implementation Plans and in the proposed Clear Skies Initiative. This research is driven by continuing pressure to further reduce NO_x emissions to address ground-level ozone and other environmental considerations, including ambient fine particulates, visibility, eutrophication, and climate change.

Projects within the NO_x program are directed at achieving NO_x emissions less than 0.15 lb/million Btu at 25 percent less than the cost for selective catalytic reduction. These projects are designed to parallel, as closely as possible, State implementation schedules with plans for commercialization in 2002 to 2003.

With the Nation's electric utility industry facing tighter controls on mercury emissions, several projects are underway to develop and test technologies that offer power plant operators better ways to reduce these emissions at much lower

cost. This research is focused on field demonstration of systems that will be commercially available by 2005, that are capable of cutting mercury emissions 50 to 70 percent, and cost less than half of today's state-of-the-art systems. For example, two projects that involve full-scale testing of advanced mercury control technologies are currently underway to:

- Demonstrate a cost-effective technology that uses a liquid reagent that enhances the capture of mercury in a wet scrubber, which is to be tested at two coal-fired electric-utility sites by McDermott Technology.

- Develop a sorbent-injection system for mercury capture to be tested by ADA Environmental Solutions at four different utility power plants.

Several additional projects are underway to develop technologies that reduce mercury emissions; these include (1) creating tools that enable us to understand the underlying principles of mercury species formation and (2) developing novel mercury-capture equipment.

The EPA's Toxic Release Inventory requires potential sources, including electric utilities, to report annual releases of a number of compounds, including acid gases such as sulfuric acid (H_2SO_4), hydrochloric acid (HCl), and hydrofluoric acid (HF). Heightened public awareness of these emissions may lead to a call for tighter emission standards. A project with URS was recently completed to demonstrate in-furnace control of H_2SO_4, HCl, and HF using alkaline sorbents at First Energy's Bruce Mansfield plant and American Electric Power's Gavin power plant.

The removal of fly ash, SO_2, and other species (i.e., mercury and acid gases) from flue gas results in the production of CUBs such as fly ash and scrubber solids. Our research program will develop new applications for CUBs, evaluate the impact of air emissions-control technologies on CUB properties, and provide data on the environmental acceptability of these byproducts. We work with regulatory agencies to produce environmental and technical guidelines and standards for CUB use, and we conduct training, outreach activities, and workshops on the use of CUBs.

The Clean Water Act and the Safe Drinking Water Act serve as the basis for a number of recent regulatory proposals and new initiatives to improve water quality in the United States. These legislative actions have driven home the critical importance that the Nation has placed on the continued availability of clean water. Furthermore, they have brought into sharp focus the potential implications that clean water regulations may have on the production of electricity from coal. To address these issues, the NETL is carrying out research directed at regional watershed issues.

We are also assessing the potential linkage between energy production, emissions, and water quality. We are identifying the impact of the development and implementation of regulations on the need for expanded and new R&D, including the development of more efficient dry-cooling technologies, improved air emissions performance, and the determination of the effect of atmospheric pollution on aquatic systems.

Investigation of Stream Sediments by NETL Researchers

NETL researchers in the Environmental Research Focus Area are pioneering the application of remote or airborne sensing technologies for an overall assessment of the impact of pollution discharge points on watersheds. In addition, NETL is carrying out research related to the development of passive and semi-passive systems for treating acid mine drainage; the use of fluidized-bed combustion fly ash to enhance settling of metals and other contaminants; and techniques to immobilize and stabilize pollutants in soils.

The NETL collaborates with the U.S. Geological Survey, EPA, Corp of Engineers, Office of Surface Mining and the States of West Virginia and Pennsylvania to standardize training for the region's volunteer watershed organizations. The general approach accepted by the team of government agencies was to create a series of training videos and make them available in both tape and html (Internet) formats.

The NETL has worked collaboratively with the Energy Information Administration (EIA) to incorporate technical performance and cost information on mercury-control technology into the National Energy Modeling System (NEMS). The NEMS model is used by the EIA to forecast energy supply, demand, and prices through 2020.

Planned Activities

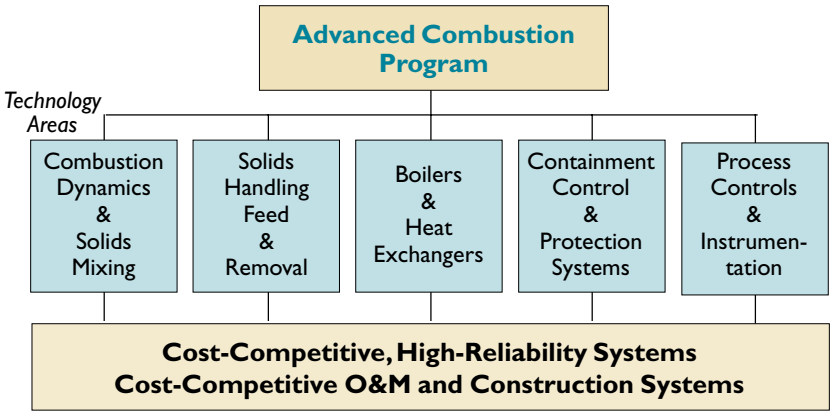
The Innovations for Existing Plants program will continue to focus on the goal of providing technologies to improve the efficiency and environmental performance of existing coal-fired power plants, and to reduce the costs for environmental compliance by 25-75 percent between now and 2008. Specifically, the program's near- and long-term plans include the following:

- Field tests of advanced systems capable of 50-70 percent capture of mercury at one-half to two-thirds the cost of today's technology.
- Pilot-scale development of advanced controls that can achieve NO_x emission limits of 0.15 lb/million Btu at three-fourths the cost of SCR.
- Pilot-scale and field tests of advanced particulate controls that can reduce fine particulate emissions by more than 99.99 percent.
- Investigation of the impacts of advanced control technology on the environmental acceptability of CUBs.
- Assessment of the need for advanced technology to address water-related issues (e.g., cooling water intake regulations under the Clean Water Act).

We expect to establish effective international partnerships whereby we will be able to expand the use of clean, efficient, fossil energy-related technologies and energy services by applying appropriate technology and our expertise to address trans-boundary pollutant issues (e.g., mercury).

3.2 Mid-term Markets

We recognize that energy issues before our Nation require constant consideration and diligent response to keep pace with the changing needs and expectations of United States citizens. Coal-based power production issues and opportunities for the 2010-2015 timeframe are addressed in this element of the program.



Program Status

R&D underway in Advanced Combustion Technologies is making substantial improvements in the performance of existing power plants, and it is paving the way for a new generation of smarter coal-based power plants that will be

Advanced Combustion Technologies Program Accomplishments

"Energy @23" Awards acknowledge market acceptance for Circulating Fluidized Bed (CFB) and Low-NO_X Burner Technologies (LNB). These awards were given to the 23 highest ranked innovations chosen from a list of 100 scientific and technological innovations made by the Energy Department between 1977 and 2000. These winning innovations successfully demonstrate benefits to the American public, a contribution to U.S. competitiveness in the global marketplace, and the potential for future growth. Because of their low cost and excellent environmental performance, both CFB and LNB are technologies of choice for new and retrofit electric power generation produced from coal.

Low waste and low emissions characterize Corn Belt Energy's new Low-Emission Boiler System (LEBS) plant that generates electricity from coal at the Turris coal mine in Illinois. Corn Belt Energy Corporation now plans to build a 91-MWe electric power plant using coal based on a LEBS design that will achieve NO_X emissions 30 percent below New Source Performance Standards (NSPS) requirements. This plant features a D.B. Riley slagging U-fired boiler that uses only 68 percent as much water as a conventional plant. Corn Belt expects this small-scale unit to generate electricity at an attractive rate of $0.03/kWh. Larger LEBS plants (in the 400-500 MWe range) are expected to achieve even lower NO_X emissions (1/10 NSPS) and use supercritical steam cycles having efficiencies in the 40-42 percent range.

Vision 21 energy plants of the future benefit from advanced materials developed under the High-Efficiency Power Plant (HIPPS) program. Oxide-dispersion-enhanced alloy materials, developed as part of the DOE HIPPS program, have shown exceptional strength and corrosion protection needed for high-temperature applications. Further development of these innovative alloys for high-temperature heat exchangers is being conducted as part of the Vision 21 program under a current effort with Huntington Alloys in West Virginia.

Vision 21 energy plants of the future benefit from heat exchanger developed under HIPPS Program. The HIPPS program developed an air heat exchanger capable of operation in coal combustion systems at temperatures greater than 2,000 °F. Reliable operation of an air heat exchanger at these high temperatures represents a breakthrough for combustion systems that will be used in future Vision 21 energy plants and as a protection device for downstream power-conversion devices like fuel cells, gas-separation membranes, and gas turbines.

High efficiency (55-60 percent) projected for advanced coal-fired power-cycle design developed under HIPPS. The two major participants in the HIPPS program, United Technologies and Foster Wheeler, each developed an advanced cycle design for coal-based power generation. Foster Wheeler's design utilizes a fluid bed partial gasifier to produce syngas for a combined cycle turbine. United Technologies worked with the University of North Dakota Energy and Environmental Research Center to develop a high-temperature heat exchanger for an indirectly fired system incorporating an advanced, combined-cycle air turbine.

more efficient and dramatically cleaner. The program provides advanced combustion technology solutions for the coal-powered generation industry in the 2005-2010 market.

The NETL Gasification program is designing novel combinations of gasification, gas cleanup, gas turbine, and synthesis gas technologies for converting all carbon-based feedstocks to a combination of products, including electricity, fuels, and chemicals. This technology offers the United States and other countries an alternate approach for providing clean, affordable electricity as well as a means for producing other valuable products to meet future market needs. Gasification is envisioned to be a technology of choice because of its economics, high thermal efficiency, superior environmental performance, and feed and product flexibility.

For many years, the DOE and industry have worked to develop the concept of integrating gasification with clean, efficient gas and steam turbines to create Integrated Gasification Combined Cycle (IGCC) power plants. This development was sparked by the need for more efficient power generation with the lowest possible emissions. The potential of IGCC technologies is now being proven in the DOE Clean Coal Technology Demonstration program. Two IGCC projects have been operated successfully and a third is in the permitting phase.

Gasification of petroleum residuals, coke, and coal for syngas for chemical production is becoming accepted worldwide. Over the next several years, gasification of coal and petroleum residuals to produce electricity is expected to increase. Beyond this, gasification must be capable of processing any carbon-based feedstock (e.g., municipal wastes, sewage sludge, and biomass) to produce a suite of products besides electricity.

Planned Activities

Tampa Electric Polk Power Station's IGCC Plant, one of the cleanest coal-fired power plants in the world and the lowest cost producer of electricity on Tampa Electric's grid, won the 1997 Power Plant of the Year Award

The Power Plant Improvement Initiative will facilitate the introduction of new technologies into the power-generation industry through demonstration projects. This new technology must advance the efficiency, environmental performance, and cost-competitiveness of coal-fired capacity well beyond that which is in operation now or has been demonstrated to date.

The Clean Coal Power Initiative (CCPI) is a cost-shared government/industry partnership to implement the President's National Energy Policy (NEP) recommendation to demonstrate advanced coal-based power-generation technologies. This NEP recommendation, one of several dealing with electricity, addresses our national challenge of ensuring the reliability of our electric supply while simultaneously protecting our environment. The first round of solicitations in the CCPI sought projects that (1) demonstrate advanced coal-based technologies, and (2) accelerate their commercial deployment. The CCPI is open to any technology advancement related to coal-based power generation that results in efficiency, environmental, and economic improvement compared to currently available state-of-the-art alternatives. In addition, the CCPI is also open to technologies capable of producing any combination of heat, fuels, chemicals or other useful byproducts in conjunction with power generation. The first CCPI solicitation was issued on March 4, 2002, with selections expected by January 2003. DOE expects to have over $300 million available to support the awards. For each project, industry shares a minimum of 50 percent of the total project cost.

DOE received 24 proposals in response to the Power Plant Improvement Initiative solicitation and made eight selections in 2001. One project has since been withdrawn, leaving the following portfolio:

- four emission control strategies,
- two advanced control schemes, and
- one waste handling/reduction project.

These cost-shared projects have a total cost estimated at about $110 million.

The Advanced Combustion Technology program provides opportunities to maintain and/or increase capacity through retrofits and repowering. The NETL is developing cost-competitive solutions for the coal-based power-generation market in six key technology areas:

- Combustion Dynamics and Solids Mixing Systems.
- Solids Handling.
- Advanced Boilers and Heat Exchangers.
- Contaminant Control and Protection Systems.
- Process Controls.
- Construction and Operation Cost Improvements.

The Power Systems Development Facility (PSDF) at Wilsonville, Alabama, provides an important pilot-scale test bed for the Advanced Combustion Technology program. It is used to demonstrate advanced technologies for pressurized combustion and hybrid systems.

The Gasification program has been restructured over the past few years to address current as well as future market drivers. The most significant drivers for future use of gasification technology include more intense competition resulting from deregulation of the power industry, stricter environmental laws, tighter regulations on product end-use applications, and controls on greenhouse gas emissions. Consideration of these drivers points to goals for power plants using gasification technology that would make them competitive in power-generation markets. To accomplish these goals, the gasification program has three component parts—Gasification Systems Technology, Vision 21, and Systems Analysis/Technology Integration.

Gasification Program Goals

- Capital costs less than $1,000/kWe.
- Minimal or no emissions of sulfur and nitrogen oxides, hazardous air pollutants, and fine particulates.
- Efficiencies equal to or greater than 60 percent.
- Ability to use a variety of feedstocks.
- An assortment of marketable products that meet market requirements.
- A cost-effective means to capture carbon dioxide.

Gasification Systems Technology research is designed to improve the reliability and availability of the gasifier and gas cleaning and conditioning technologies. The expected result of these efforts is the development of advanced gasification concepts and improvements to materials, instrumentation, and controls.

Vision 21 elements included in the Gasification program center on the development of "step-out" technologies to achieve high efficiency and near-zero emission targets. Research in this area focuses on development of ion-transport membranes for air separation, coproduction, ultraclean gas, hydrogen/carbon dioxide separation, alternative feedstock utilization approaches, and novel gasifier concepts.

Onsite research contributions to Vision 21 technologies focus primarily on developing advanced gas-cleaning technologies, hydrogen separation, simulations, and instrumentation and control systems. Activities range from fundamental laboratory studies of high-temperature sorbents, through dynamic simulation of advanced gasification systems, to engineering-scale research in transport and fluidized-bed gas cleanup in a Gas Process Development Unit.

Systems Analysis/Technology Integration provides process engineering and analyses to guide current and future R&D efforts, define new initiatives, establish R&D objectives, and support commercialization activities. Investigating the coproduction of power and other products is a key element of this activity.

In the near term, the Gasification program will refine its long-term research strategy based upon technology needs and requirements identified through interactions with various stakeholders.

The Gasification/Combustion Hybrids program explores the feasibility of systems that partially gasify coal to produce syngas that could be used as fuel in a turbine while the remaining char is burned in a high-efficiency atmospheric-combustion system.

3.3 Vision 21—Future Energy Plants

FE has begun a new approach for developing 21st century energy plants with dramatically enhanced environmental characteristics. Called "Vision 21," this new approach is timely because of unprecedented changes in the electric power industry. These changes include electric utility deregulation and restructuring, and a new emphasis on environmental issues, including global climate change and pollutant emissions (NO_x, SO_x, $PM_{2.5}$, and Hg).

Program Status

The Vision 21 concept has been expanded into a clearly defined program that by 2015 provides a pathway to ultraclean fossil-fuel-based energy plants capable of having virtually zero environmental impact. The NETL has held workshops with industry, academia, and other government organizations to gather input on the drivers for, and research and development needs of, a Vision 21 program based on these premises:

- We need to rely on fossil fuels for a major share of our energy needs well into the 21st century.
- It makes sense to rely on a diverse mix of energy resources, including coal, gas, oil, biomass and other renewables, nuclear, and "opportunity" resources rather than on a limited subset of these resources.

The goal of the Vision 21 program is to effectively remove all environmental concerns associated with the use of fossil fuels for producing electricity, liquid transportation fuels, and high-value chemicals. This will be accomplished by implementing an aggressive government/industry cost-shared program.

Better technology can make a difference in meeting environmental needs at an acceptable cost. Different kinds of power systems, each based on a different technology, are being developed under the DOE Fossil Energy R&D Program. Any one of these technologies alone (e.g., gasification combined cycle, advanced turbine systems, fuel cells, advanced pulverized coal combustion, indirectly fired cycles, or pressurized fluidized-bed combustion), cannot achieve the efficiency, environmental performance, and costs needed to achieve the Vision 21 goal.

Vision 21 focuses on systems and components that integrate multiple technologies to achieve substantial improvements in performance and cost. The key technologies needed to realize Vision 21 have been identified in concert with industry. These key technologies include advanced gas-separation and purification systems, fuel-flexible gasifiers, high-performance combustion systems, gas turbines, fuel cells, improved materials, and advanced fuel and chemical synthesis concepts. Vision 21 efforts focus on developing the scientific and technological advances needed in these key areas. System integration is especially important because it will inform us on how to deal with the complex engineering challenges involved in interfacing advanced modules, such as gasifiers, turbines, and fuel cells, into an ultrahigh-efficiency, superclean energy facility. Furthermore, Vision 21 emphasizes market flexibility, feedstock and product flexibility, and industrial ecology concepts.

Planned Activities

Thirteen industry-led advanced research and engineering projects that begin the effort to design the Vision 21 energy plants of the future have been awarded. These projects initiate the work of developing the critical building blocks, or "technology modules," that will be integrated to create revolutionary Vision 21 plant designs that may be available for commercial construction and demonstration by 2015. The total value of the projects, which are nominally 3 years in duration, is $32 million ($24 million from DOE and the balance from private cost sharing).

An Artist's Rendition of a Vision 21 Plant

Innovations under development in these projects may revolutionize the way we generate electricity by 2015. Three concepts that push technology to new limits are (1) gasification-combustion technology to convert coal to hydrogen and CO_2 for sequestration; (2) a fuel-cell, gas-turbine hybrid to generate electricity at unprecedented efficiency; and (3) a rocket engine design adapted for turbine power. The first concept produces pollution-free electricity using turbines or fuel cells and enables the construction of fuel-flexible, highly efficient, economically viable central station power plants. The second concept integrates fuel cells and turbines and could stimulate new utility markets for high-efficiency power plants (efficiencies from 65 percent in the near-term to greater than 75 percent by 2015) with near-zero emissions. The third concept combines a revolutionary steam generator adapted from rocket engine technology and an advanced turbine to achieve 60-65 percent efficiency, nearly double that of traditional coal-fired power plants. Water and sequestration-ready CO_2 are the only emissions, and both may be collected.

Engineering issues associated with integrating key components and subsystems into Vision 21 plants are being defined. Computer software to simulate gas-particle flow in fluidized beds, including gasifiers, fluidized bed combustors, and pneumatic transport, will be developed. Materials developed will include stronger, corrosion-resistant, high-temperature oxide-dispersion-strengthened alloys for heat exchangers. Some other technology developments that have been initiated include:

"The goals for the Vision 21 program are very ambitious. If these goals can be achieved, Vision 21 technologies would offer the United States, and the world, a new method of coal-based power generation that would have significant advantages over current methods."

National Research Council

- A ceramic membrane to separate hydrogen from gas streams.
- A zero-emission power plant integrating solid oxide fuel cells with oxygen-separation membranes.
- A pressurized circulating fluidized-bed partial gasification module that produces gaseous and solid fuels for use in fuel-flexible high-efficiency plants.

Methods for scientific and engineering RD&D are rapidly evolving as a result of advances in our basic knowledge of chemistry and physics and the growth in the memory, capacity, and speed of computers. Computational evaluation of new concepts can lead to scientific insights that might not result from experimental research alone. Science-based simulations, conducted in parallel with experimental research, can result in much faster system development at lower cost, while reducing financial and operational risks in construction and commercialization.

For many years, we have enjoyed a distinguished history of developing mathematical simulations and models of fossil energy subsystems such as gasifiers, combustors, and gas cleanup systems; and we have worked with experimental researchers and industrial organizations to effectively use these models to improve process performance. For example, this work led to a mathematical description of the physics of dense multi-phase flow that is implemented in the NETL-developed, open-source research code MFIX and is now being incorporated into Fluent™, a commercial computational fluid dynamics code. Our onsite computational research has also led to better simulations of underground gas and oil reservoirs.

The mission of Computational Energy Science Focus Area at NETL is to develop science-based computational tools and apply them to simulate clean, highly efficient energy plants of the future. This Focus Area develops a set of rigorous but flexible computation tools that will allow more rapid and efficient scale-up of new subsystems, devices, and components. It will expedite and minimize cost, or reduce the need for large and expensive demonstration-scale testing of Vision 21 integrated energy systems. Work in the Focus Area complements RD&D activities sponsored by the Vision 21 program and other related FE programs.

Capitalizing on this talent available at the NETL, we have initiated a major thrust, the Focus Area in Computational Energy Science. One purpose of the focus area is to use advanced simulation techniques to improve and speed the rate and quality of development of cleaner, more efficient energy devices and plants. This fundamentally alters the paradigm by which advanced energy plant concepts are developed.

The goal of this Focus Area is to develop a "virtual demonstration" capability. It will predict dynamic responses of entire energy systems, including interactions of turbines, fuel cells, combustors, environmental control systems, and other major components. Further, it will permit analysis, diagnosis, and verification of results from testing of prototypal systems and systems interfaces. The Focus Area crosscuts and supports three other onsite Focus Areas at the NETL. It also provides computational science expertise in areas such as natural gas production and watershed research. The activities of the Focus Area support many of our programs, including advanced power generation and clean-fuel technologies.

Activities in this Focus Area will address the following scientific or technical challenges:

- ***Complex chemistry and physics of reacting flows***—Provide insights into the complex interactions of physical and chemical systems encountered in advanced energy plants using computational research. Science-based simulation will be used to explain the operation of complex systems, predict their performance, and suggest ways to significantly improve their effectiveness and efficiency. In these activities, the Focus Area collaborates with other DOE national laboratories involved in fundamental computational science and mathematical simulation activities.

- ***Modeling of novel devices and processes***—Develop computational models of flow in gas turbines, models of combustion, gasification, and contaminant control processes, and simulations of energy-related systems, such as underground reservoirs. Focus Area expertise is being applied to energy-related processes to develop and use simulations of energy devices and to investigate device-level dynamic control strategies.

- ***Visualization and computational strategies***—Collaborate with the Pittsburgh Supercomputing Center, West Virginia University, other DOE national laboratories, DOD laboratories, and NASA laboratories to develop visualization hardware and software, data-mining methods, and other technologies to ensure maximum utility of simulation results.

- ***Virtual demonstration***—Develop the capability to allow prediction of dynamic behavior of entire energy systems, such as Vision 21 plants, to reduce the time and cost of overall development and demonstration of energy systems. Mechanistic models of system elements will be combined in integrated simulations, using 3-dimensional visualization methods, computer-aided design tools, data bases, and control strategies, to provide a model of the overall energy plant. In these activities, the Focus Area collaborates with Carnegie Mellon University, advanced computation companies, such as Fluent and Intergraph, and industrial organizations, such as ABB Asea Brown Boveri, Ltd., etc.

The Focus Area will use state-of-the-art computing systems to design, model, and simulate the operation of futuristic power plants. These high-powered computers are available to the NETL through membership in the Supercomputing Science Consortium. This collaboration with the Pittsburgh Supercomputing Center and other organizations permits access to one of the fastest computers in the world, with teraflop-level computational capability.

3.4 Clean Fuels from Coal

Our large domestic resources of coal can provide (1) clean, high-performance liquid fuels needed in the mid-term for advanced engine/aftertreatment systems and (2) pure hydrogen for fuel cells. In addition to energy security issues, major challenges facing transportation are urban and regional air pollution and emissions of greenhouse gases. As the Nation transitions toward ultralow-emission vehicles and eventually near-zero-emission vehicles, such as that proposed in the Administration's recently announced initiative to develop the fuel-cell-powered "Freedom Car," there will be a need to develop clean fuels for both of these scenarios.

- Our national security is threatened by increasing dependence on imported petroleum from unstable world regions.
- Experts predict world oil production will peak in first half of this century.
- Transportation is a major contributor to regional air pollution (CO: 80 percent, NO_x: 50 percent, VOC: 40 percent) and clean fuels are essential to mitigate this.
- Transportation is responsible for one-third of U.S. greenhouse gas emissions (~ 500 million metric tons).
- Affordable transportation is essential for our continued economic prosperity.

In addition to premium liquid fuels and hydrogen, coal can produce other high-value products. Coal can be used to make high-purity carbon electrodes and specialty graphites that are of better quality than those made from conventional processes that rely on petroleum coke. Composite fuels consisting of coal and waste biomass can help offset the release of greenhouse gases during combustion. Throughout the U.S. coal-producing regions, there are large amounts of coal residing in waste ponds. Separation processes to economically recover the coal could make it available for power generation and, concurrently, eliminate existing and potential environmental problems associated with these waste sites.

The NETL recognizes the need to make the United States less vulnerable to international energy crises and fuel shortages; improve the environmental performance of every component in the fuels productions, processing, delivery, and utilization chain; and make possible a significantly cleaner and more efficient transportation fleet. We have developed partnerships with other government agencies and all elements of the fuels and transportation industries, including fuel producers, technology developers, and engine and emission control manufacturers. In conjunction with these partners, we have designed our fuels RD&D programs to address the issues that industry and our Nation face.

3.4.1 Transportation Fuels and Chemicals

Research efforts are focused to develop technologies for making clean liquid fuels, hydrogen, and fuel additives and lubricants from domestic coal-derived synthesis gas. The outcome of these research efforts will provide the transportation sector with significant environmental benefits and help to diversify our domestic resource base for the production of fuels.

Hydrogen has been recognized for many years as the premier fuel for emissions-free transportation. In early 2002 the Administration announced the "Freedom Car" initiative, which has increased interest in pursuing the research needed to satisfy the demands of future hydrogen-fueled, fuel-cell-powered vehicles. Coal contains the largest domestic resource of hydrogen, but significant issues must be addressed to ensure that coal-derived hydrogen is produced, delivered, and stored in a manner that is safe, environmentally acceptable, and economic.

Program Status

The Transportation Fuels and Chemicals program encompasses a broad range of activities designed to provide the technical means to produce liquid fuels and hydrogen from coal. This program involves investigations that range from laboratory-scale studies of new fuel-making concepts to proof-of-concept testing at the Alternative Fuels Development Unit (AFDU) located in La Porte, Texas, and operated by Air Products and Chemicals, Inc. (APCI). The plant uses synthesis gas (hydrogen and carbon monoxide) from a nearby APCI facility as the reactant for producing a wide range of high-value products in quantities up to 35 barrels per day. The specific product slate is determined by the hydrogen-to-carbon-monoxide ratio of the synthesis gas, the reactor operating conditions, and the catalyst used.

NETL onsite researchers in the Clean Fuels Focus Area have constructed and are operating a versatile membrane test unit that enables manufacturers to quickly test hydrogen separation membranes over a wide range of temperatures and pressures and subsequently do detailed analyses of the effect of operating conditions on the membrane. The unit and the research team are an important component in the Nation's move toward greater hydrogen utilization.

The AFDU is the premier unit of its size, and the only operational fuel process development unit in the world that is available to technology developers on a nonexclusive basis.

In 1998, the coal fuels research activities were enhanced through a joint effort with the NETL's Gasification Technologies product line to sponsor the development of technologies that coproduce some combination of power, fuels, and chemicals. Coproduction involves the integration of (1) coal gasification to produce synthesis gas, (2) conversion of a portion of the synthesis gas to high-value fuels and/or chemicals, and (3) combustion of the remaining synthesis gas to produce electric power. This strategy makes more efficient use of capital than producing power alone. The two industry-led coproduction teams have completed their technical-economic analyses and are performing the R&D tasks needed to reduce the risk of integrating the fuel and power systems. Government sponsorship will conclude with preparation of preliminary engineering designs for each plant concept.

In the process of gasifying coal to produce pure hydrogen, it must be separated from the many other gases that are produced. Because of this, hydrogen separation membranes are a key component to enable economic, widespread use of hydrogen in fuel-cell-powered vehicles.

Planned Activities

The research associated with the Laporte AFDU facility will be continued. Specifically, the AFDU will be maintained in an operational status, instrument and software upgrades will be added, laboratory research will focus on extending catalyst life, and a three-phase slurry reactor hydrodynamics will be investigated. We will also create a program structure that incorporates other important fuels research elements directly related to meeting the Office of Fossil Energy's goals. Some specific aspects of this strategy include:

- Strengthening our collaborations with the military by developing coal-derived liquid fuels and hydrogen for strategic military applications and determining their capability to enhance operational readiness.
- Conducting research in the NETL Clean Fuels Focus Area that will facilitate the deployment of fuel-cell-powered vehicles and applying computational fuel science that offers step-out advances in the design of coal fuels processes and significant reductions in technology development time and costs.
- Completion of the Early Entrance Coproduction Plant projects that can lead to economically and environmentally advantageous means to achieve the Nation's energy goals with coal by producing a market-driven combination of clean products, including hydrogen.

3.4.2 Advanced Fuels Research

The Advanced Fuels Research program acts as a bridge between basic and applied research and meets two major needs. The first is the fundamental information and knowledge needed to surmount technical barriers encountered in studies of advanced fuels. The second is the exploration and evaluation of innovative concepts and ideas that anticipate requirements and advances in fuel formulations and fuel use technologies that, if successfully developed, would enhance the overall pace of technology development. Both needs could be met by developing a readily transferable knowledge base of the chemical and physical processes underlying advanced technologies. This "supporting science" will address key technology barriers, R&D opportunities, and research requirements.

Program Status

NETL onsite researchers in the Clean Fuels Focus Area are evaluating the properties of single-wall, carbon nanotubes to determine their potential for use as hydrogen storage media. These tubes have been reported to have hydrogen storage properties exceeding what would be expected from simple adsorption processes. Understanding how to effectively use carbon nanotubes could be an important part of a "hydrogen economy," as they would provide a safe method of hydrogen storage for fuel-cell-powered vehicles.

Key areas shaping the Advanced Fuels Research program include the production, purification, and storage of hydrogen produced from coal and the use of "C-1" chemistry (see next paragraph) to produce environmentally desirable fuels and fuel additives. The ability to produce hydrogen from coal with minimal emissions early in a transition to a so-called "hydrogen economy" would help to facilitate this transition by promoting the continued use of fossil fuels. Work in synthesis gas chemistry, the computational chemistry of the many aspects of fuels production, and methods for the rapid screening of desulfurization processes are being pursued.

"C-1" chemistry is defined as the chemistry of compounds containing a single atom of carbon. The C-1 compounds of greatest interest to the Department are methane, carbon monoxide, carbon dioxide, and methanol. Significant environmental benefits will accrue from an understanding of the chemical and physical processes needed to transform these compounds into various fuels and fuel additives that may be produced from domestic resources. The most comprehensive work in this area is being undertaken by the Consortium for Fossil Fuel Liquefaction Science, a research consortium with participants from the University of Kentucky, West Virginia University, the University of Utah, the University of Pittsburgh, and Auburn University. This consortium has enlisted the help of an Industrial Advisory Panel, which enhances the academic research with firsthand knowledge of industry concerns and needs. The consortium pursues catalyst development and investigates the chemistry of Fischer-Tropsch (F-T) fuels, methanol, complex oxygenate synthesis, oxygenated additives for gasoline and diesel, hydrogen production, and synthesis gas production.

Work at Research Triangle Institute also investigates the F-T reaction for fuel production with a goal of changing the distribution of the products. This is important to the commercial application of F-T processes because it will reduce post-production-processing costs and increase yields of clean transportation fuel.

The development of attrition-resistant catalysts for multiphase chemical reactors may have far-reaching effects. Research is directed toward protecting catalysts with a porous, attrition-resistant coating, allowing use of proven catalytic materials in new, efficient chemical reactors to produce fuels and chemicals.

Allied work involves the development of a computer model that describes the exceptionally complex hydrodynamics of a multiphase reactor. This model, when complete, will greatly assist in determining the optimum size and shape of the reactor and its internal components.

Planned Activities

As budgets permit, high-priority research concepts will be pursued to remove barriers and permit the achievement of DOE/FE/NETL objectives.

3.4.3 Solid Fuels

The goal of the Solid Fuels program is to provide the scientific and engineering knowledge base that could enable industry to produce economically competitive and environmentally acceptable products and feedstocks from coal and mixtures of coal and other resources. Advanced separation technologies will allow companies to extract, process, and dispose of coal and mineral substances without objectionable social and environmental costs, and to reclaim valuable resources from wastes. Many of the advanced separation technologies to be developed will have crosscutting applications to a variety of other industries.

Recently, utilities have begun to cofire biomass and waste materials with coal in specialized applications where there is a ready supply of waste biomass. Cofiring renewable fuels with coal offers the advantage of reducing the net production of CO_2 from the use of fossil fuels. A better understanding of the technical requirements for cofiring biomass and coal could increase its use. Even with moderate growth over today's level of deployment, the resulting reductions in CO_2 emissions could provide a significant benefit.

All ranks of coal (anthracite, bituminous, subbituminous, and lignite) could prove to be good feedstock substitutes for petroleum-based materials for the manufacture of premium carbon products. Coal-derived specialty graphites are considered to have higher purity, strength, and isotropy than those derived from petroleum. Anthracite offers promise because of its high carbon and low sulfur and ash content, and high-volatile bituminous coal shows promise as a source for binder pitch when extracted with appropriate solvents. Once low-cost processing technologies are developed, coal will naturally find uses in other carbon products because of its surety of supply and widespread availability. Advanced separation technologies will allow companies to extract, process, and dispose of coal and mineral substances without objectionable social and environmental costs, and to reclaim valuable resources from wastes. Many of the advanced separation technologies to be developed will have crosscutting applications to a variety of other industries.

Program Status

The Solid Fuels program is conducting research in the following areas:

- Premium carbon products.
- Direct reduced iron.
- Advanced separations technology for mining and minerals applications.

Several activities are ongoing to develop premium carbon products. A coal extraction process under development by West Virginia University holds promise as a cost-competitive source of improved binder pitch, carbon fibers, and carbon structural foams. Coal tar pitch, the binder commonly used in anode production and other carbon materials applications, is a byproduct that is generated during coke production. Because of aging coke batteries, a declining steel industry, and more stringent environmental regulations, the continued availability of sufficient tar of the required quality is in doubt. The coal extraction process under development uses a recoverable solvent to extract a material from bituminous coals that is similar in properties to coal tar pitch. The production of a consistent, high-quality product is a key advantage of extraction methods for making pitch precursors from coal. Other products that could result from this approach include (1) binders, (2) mesophase and isotropic pitches (as carbon foam and fiber precursors), (3) coke feedstocks (for needle, sponge, and specialty cokes), and (4) impregnation pitches. At this time, the process is being scaled up to demonstrate the technology and generate enough extract to determine its suitability to yield other products.

The NETL, Pennsylvania State University, and West Virginia University are leading the Consortium for Premium Carbon Products from Coal. This industry-driven consortium (with nearly 50 industrial and academic members) identifies, selects, and cofunds research initiatives focused on producing value-added carbon products. The industrial members often partner with academic institutions in cost-shared (the private sector provides at least half of the funding) research projects that seek to commercialize carbon products derived from coal. These projects are diverse and broad in scope (e.g., one project demonstrated the ability to reactivate carbon adsorbents used to purify drinking water at the Cincinnati Waterworks).

Efforts to address steelmaking issues are exemplified by a project to investigate a process to produce direct-reduced iron from coal, iron concentrate, and limestone. These materials, the lowest cost raw materials available for the production of iron, are being combined at high temperature in a simple, low-cost tubular reactor to produce iron at a cost expected to be at least 40 percent less than that for any other existing process.

The NETL is developing processes to produce solid fuels containing biomass that could be used for cofiring; examples include the following:

- Composite solid fuel formed by combining sawdust and fine coal.
- Char formed by pyrolyzing wastewater treatment sludge.

Advanced separations technology is being applied to the dewatering of coal fines to allow the recovery of coal from settling ponds as a fuel and to eliminate the future need for these ponds and the hazards they pose. Furthermore, technology is being developed to separate carbon particles from power plant fly ash. Technologies to reduce NO_x emissions at power plants change the characteristics of the fly ash collected. If the carbon particles remain in the fly ash, beneficial uses of the fly ash (e.g., to make cement) may no longer be possible. Instead, the fly ash containing carbon particles may require disposal as a waste material in a landfill. Removal of these carbon particles produces a high-surface-area carbon that could be used as a sorbent to reduce emissions of air toxics, such as mercury, from power plants.

Planned Activities

As budgets permit, high-priority research concepts will be pursued to remove barriers and permit the achievement of DOE/FE/NETL objectives. For example:

The recent creation of the Center for Advanced Separations Technology (CAST) located at Virginia Tech and West Virginia University will provide the scientific basis for development of advanced solid-solid and solid-liquid separation technologies important to the mining and minerals industry. Further, technology is being developed to recover power plant fly ash from settling ponds. Recovery includes separation of the fly ash into several distinct product streams, including two carbon streams for fuel or sorbent use, and several mineral streams for resale to the cement industry.

The Consortium for Premium Carbon Products from Coal will continue to match industry needs with university researchers in efforts to expand the uses of coal. New work will include further development of technology to produce carbon fibers and foams from coal, and production of carbon materials from anthracite.

If the initial phase of the steelmaking project is successful, research will be conducted to determine the yield and energy requirements for converting the direct-reduced iron into “hot metal” using pressurized air and oxygen, and an assessment of ingot quality will be made.

3.5 Mining/Water: Addressing Energy Supply Issues

Historically, technology has been a critical success factor in the mining industry's ability to reduce environmental impacts and occupational hazards while continuing to increase productivity and cut costs. Satellite communications systems and information processing technologies are already reducing costs and minimizing environmental disruption associated with reserve characterization and production. Automated machines reduce worker exposure to hazards, while in-situ processes contain the disruption associated with extraction and processing. As the mining industry advances into the 21st century, the opportunity to successfully apply emerging technologies to enhance production and resource performance and provide new products is critical to the industry's ability to serve the Nation and achieve profitability. Once these technologies are developed and practicable, they will enable the industry to use energy, land, capital, and labor resources even more efficiently during all stages of the mining cycle. This will, in turn, create a safer, environmentally benign industry, with higher quality output at a reasonable cost.

The Mining/Water program is tailored to restore ecosystem health

Program Status

The Mining Industry of the Future program, one of several energy- and waste-intensive industries under EE's Office of Industrial Technologies, mobilizes the combined capabilities of the DOE national laboratories, universities, and industry to accelerate technology research, development, and deployment. This program is guided by two technology roadmaps developed jointly by industry and DOE. The program areas of the technology roadmaps are Mineral Processing Technologies and Crosscutting Research. The NETL supports this program by performing procurement and project management services that include solicitation development and proposal evaluation and selection.

Our onsite research capabilities in Watershed Management include the development, design, and evaluation of active and passive water-treatment systems, and problem solving at active and abandoned mining operations.

Because regional watersheds cannot be adequately restored unless all parties are working together, a community-based approach to the Watershed Management program is being pursued to improve water quality. Many organizations—citizen action groups; industry; academia; Federal, State, local, and tribal governments; and the general public—need to work together to assess and solve diverse problems facing the Nation's water resources.

In our regional watershed in northern West Virginia and southwestern Pennsylvania, with participation by the NETL Environmental Research Focus Area, we apply the principles of community involvement to help develop, promote, implement, and monitor watershed projects tailored to restore ecosystem health and viability.

Through the National Park Service, we also are providing (1) direct technical assistance, as well as contracting and project management services, to help restore a watershed on the Kentucky-Tennessee border and (2) direct technical assistance to environmental cleanup efforts at an abandoned copper mine and mill in Vermont.

Planned Activities

The Mining Industry of the Future program will continue to focus on improving energy efficiency in mining and processing operations. In pursuit of this goal, a technology roadmap will be developed for the Mining Technologies area of the program.

Future technical activities under this program will include:

- Robotics testing on large-scale equipment.
- Real time ore grading.
- Drilling and blasting optimization.
- Improved underground communications.
- Machine analysis.
- Imaging ahead of mining.
- Fine particle separations.
- Three-dimensional simulation.
- Mineral byproduct evaluations.

There are critical issues facing the industry today that go beyond the scope of the existing technology-based program. The NETL will address these critical issues in the near term:

- Land access.
- Land use.
- Environmental impacts.
- Improved regulatory and permitting practices and supporting science.

While the resolution of these issues will benefit all mineral extraction activities, they are of special importance to coal.

Mining Industry of the Future Program Goals

- Minimize the impact of coal and mineral mining activities on the environment and the community by fully integrating environmental goals into production plans and by practicing industrial ecology concepts.
- Use advanced technologies and training to improve worker environment, and reduce worker exposure hazards to near zero.
- Develop ways to find and define larger high-grade reserves with minimal environmental disturbance.
- Use advanced technologies to improve process efficiencies from exploration to final product.
- Maintain existing markets and create new markets for mining products by producing clean, transmutable or recyclable, and efficiently transportable products. Form cooperative alliances with the processing and manufacturing industries to jointly develop higher quality and environmentally benign products.
- Work with government to develop technologies, processes, and policies that can acceptably reduce resource development cycle time by two-thirds.
- Make careers in the mining industry attractive and promising in order to attract the best and the brightest students.

3.6 Carbon Sequestration: Important Options and Sensible Approaches to Address Climate Change

Increasing concentrations of CO_2 and other greenhouse gases in the Earth's atmosphere enhance the natural greenhouse gas effect, and may lead to changes in the climate. Global use of fossil fuel emits 7 billion tons of carbon into the atmosphere annually. Human-induced land-use changes and deforestation also help to increase the concentration of CO_2 in the atmosphere. The Intergovernmental Panel on Climate Change has predicted future emissions of CO_2. A scenario from its Second Assessment Report shows emissions of CO_2 increasing to about 19 Gt/y by 2100. The pre-industrial concentration of CO_2 was 280 ppm in the atmosphere; today it is 370 ppm, and, based on this scenario, it is predicted to reach about 700 ppm by 2100 and continue increasing. This particular scenario is sometimes referred to as "business as usual," but it already allows for substantial improvements in energy efficiency and introduction of alternative energy sources.

Measures such as improved energy efficiency and use of alternative energy sources will help reduce emissions. Because about 85 percent of the world's commercial energy needs are supplied by fossil fuels, rapid change away from fossil fuels is unlikely to be achieved without serious disruption to the global economy. It is recognized that the accumulation of atmospheric CO_2 from fossil-fuel combustion could be reduced significantly by the use of carbon-sequestration technologies. Carbon-sequestration technologies are intended to capture and store CO_2 for long periods of time. Capture and storage of CO_2 may, therefore, provide a means to rapidly reduce CO_2 emissions in the atmosphere while still using fossil fuels.

New knowledge, acquired through further research, is required to improve the efficiency and reduce the costs of carbon sequestration, particularly approaches to capture CO_2, and to address environmental impacts and the long-term reliability of storage options. There are considerable opportunities for new and novel research ideas to accelerate the development and introduction of CO_2 capture and storage technology.

Program Status

In 1998, the U.S. Department of Energy established the Carbon Sequestration R&D program with the vision of bringing certain carbon-sequestration concepts to the point of deployment. The Carbon Sequestration program provides long-range options for drastically reducing CO_2 emissions from fossil-fuel-fired heat and power facilities. This program encompasses research and field testing of a wide range of carbon-sequestration options including geologic, ocean, terrestrial, and other innovative approaches. It employs economic assessments and systems studies to help guide the research. The Carbon Sequestration Science Focus Area is part of the overall Carbon Sequestration program.

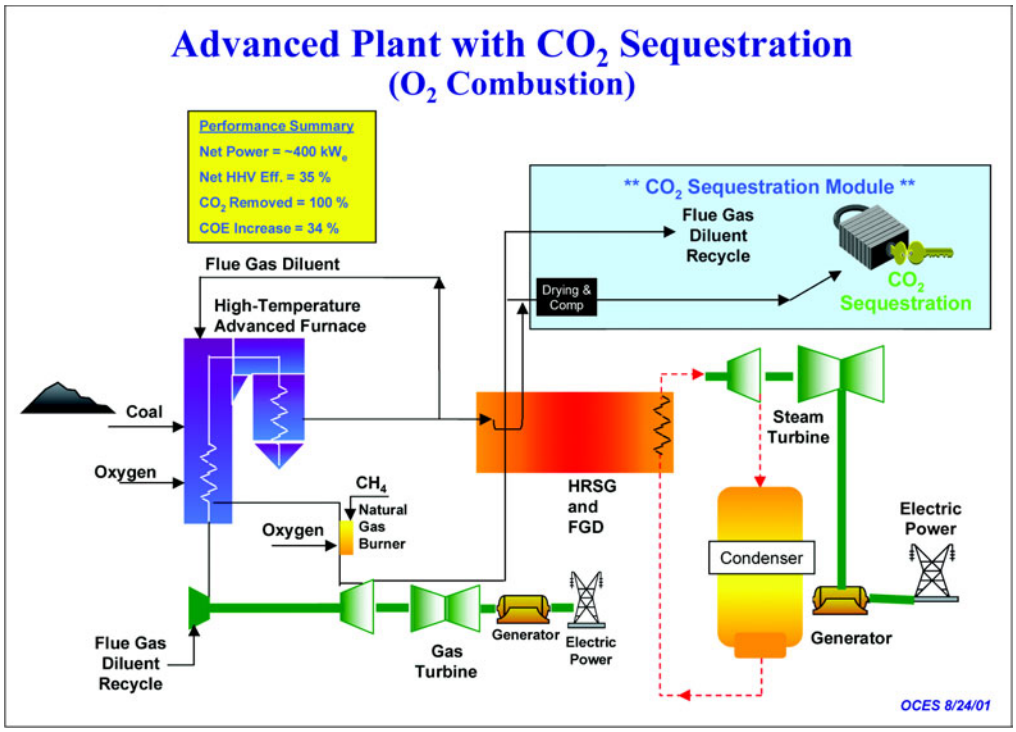
Carbon Sequestration Program Objectives

- Drive down the cost of CO_2 separation and capture from energy production and utilization systems.
- Establish the technical, environmental, and economic feasibility of carbon sequestration using a variety of storage sites and fossil energy systems.
- Determine the potential environmental acceptability of large-scale CO_2 storage.
- Develop opportunities to integrate fossil energy technologies with natural carbon sinks.
- Develop innovative technologies that produce valuable commodities from CO_2.
- Incorporate carbon sequestration processes into advanced energy-production and utilization systems.

To date, the program has initiated 29 new projects using competitive award procedures. Industry interest in these program solicitations has been strong as evidenced by the large pool of proposals and the high level of industry cost-share offered.

The five carbon-sequestration pathways outlined below, plus a crosscutting Modeling and Assessment area, constitute the research and development portfolio of the program. These pathways were identified through a collaborative effort with the DOE Office of Science.

- ***Separation and Capture***—Targets novel, low-cost approaches for removal of carbon or CO_2 from energy production and conversion systems.
- ***Sequestration of CO_2 in Geologic Formations***—Assesses the applicability and effectiveness of long-term CO_2 storage in geologic structures such as oil and gas reservoirs, unmineable coal seams, and deep saline reservoirs.
- ***Carbon Sequestration in Terrestrial Ecosystems (forests, soils, and other vegetation)***—Examines the potential to enhance the natural terrestrial uptake and retention of atmospheric CO_2 by coupling improved agricultural and forestry practices with fossil-energy production and use systems.
- ***Ocean Sequestration***—Examines potential mechanisms to enhance ocean storage of atmospheric CO_2 through processes to speed CO_2 uptake by the oceans or to inject CO_2 for deep-ocean storage.
- ***Advanced Conversion and Utilization***—Examines novel approaches to chemical, biological, or other processes to recycle or reuse the CO_2 that is produced in energy systems.
- ***Modeling and Assessments***—Provides the means to define and assess R&D opportunities and results within the five main research areas.



Planned Activities

The Carbon Sequestration program is in a technology-development phase, having conducted numerous exploratory projects to identify promising approaches and fruitful research pathways. Future plans include field trials of sequestration concepts geared toward showing technical and economic feasibility. Early tests will involve sequestration experiments where collateral benefits are likely, such as storing CO_2 in depleted oil and gas reservoirs where additional hydrocarbons may be produced, and sequestering CO_2 in coal seams in conjunction with coalbed methane production. The main driver, however, is to acquire the data and knowledge necessary to ensure the safety of, and gain public acceptance for, large-scale CO_2 storage projects.

Carbon Sequestration Research and Development Program Goals

Complete initial field-testing experiments, and produce important science and technical information on depleted oil and gas reservoirs, oceanic environments, and terrestrial ecosystems to reduce costs, ensure safety, and gain public acceptance of potential and promising large-scale carbon sequestration approaches by 2005.

In partnership with industry, academia, and research organizations, enhance the slate of carbon sequestration technology options under development to reduce greenhouse gas emissions, resulting in a robust portfolio of options to mitigate emissions from fossil fuel production and utilization systems in multiple geographic locations in the United States and abroad.

Focus U.S. research efforts towards key scientific breakthroughs needed to develop safe, cost-effective carbon-sequestration technologies.

Sponsor the first National Conference on Carbon Sequestration and facilitate continued scholarly discussions and sharing of significant findings and results.

The mission of the Carbon Sequestration Science Focus Area is to conduct scientific research that leads to the development of economical and environmentally sound sequestration options.

Additional efforts will develop advanced conversion mechanisms and utilization technologies where carbon can be converted either to stable compounds or to beneficial products.

The NETL Office of Science and Technology has implemented the Carbon Sequestration Science Focus Area. The Focus Area includes exploratory studies on advanced chemical and biological concepts, and development of computer-based systems models that can be employed to assess the performance, safety, and cost of sequestration approaches developed by the NETL and other program participants.

Operating in conjunction with our partners in industry, academia, and other national laboratories, the Carbon Sequestration Science Focus Area is addressing the following scientific issues:

- ***Improvements in Carbon Dioxide Capture*—Application of innovative sorbents:** Identify sorbents that are more efficient and less expensive than, for example, commonly used ethanolamine, and more resistant to attrition and sintering during regeneration than those currently available. The fundamental physics and chemistry of CO_2-capture mechanisms are also being explored.

- ***The Science of Sequestration*—Understanding of the underlying chemistry:** Develop science-based simulations of the complex multi-phase chemistry and flow behavior of CO_2 and other materials (e.g., surfactants) used when injecting CO_2 into sequestration sites. This work is being performed in conjunction with the Computational Energy Science Focus Area.

- ***Stability of Sequestration Options*—Feasibility of aqueous disposal:** Conduct research to better understand the long-term scientific issues related to CO_2-sequestration stability in aqueous disposal environments, such as saline aquifers and ocean-disposal sites. Supporting simulations are being developed in conjunction with the Computational Energy Science Focus Area.

- ***Systems Assessment*—Assessment of sequestration systems:** Develop and apply systems analysis tools to assess the impacts of our research program on overall economics and feasibility of sequestration policy options.

Other activities include working with stakeholders to issue a Carbon Sequestration Technology Development roadmap, developing and implementing a strong public outreach plan, and analyzing multi-pollutant control strategies that allow for integrated approaches to reduce CO_2, SO_2, NO_x, and mercury emissions.

4 Strategic Center for Natural Gas

In December 1999, the National Petroleum Council (NPC) issued its report, *Meeting the Challenges of the Nation's Growing Natural Gas Demand*, to the Secretary of Energy. This report recommended that government and industry cooperate to establish a strategy for natural gas as part of the Nation's energy portfolio. Specifically, the NPC recommends that gas technology development be accelerated, an Interagency Work Group on natural gas be created to work with industry and other stakeholders, and that balanced, comprehensive policy and regulatory approaches be established to develop the Nation's gas resource base. Other NPC recommendations addressed planning for capital, infrastructure, and human resource needs; streamlining government processes for gas development; assessing environmental regulations; and developing new services for customers.

Responsibility for DOE's natural gas RD&D programs is distributed among several departmental entities, most notably Fossil Energy (FE), the Office of Energy Efficiency and Renewable Energy (EE), and the Office of Science (SC). As the importance of natural gas to the U.S. energy mix increases, so does the importance of ensuring that DOE activities are well integrated. On December 10, 1999, the Strategic Center for Natural Gas (SCNG) was established at the NETL to provide the coordinated focus needed to achieve environmental and economic benefits of increased natural gas use.

Market forces have increased demand for natural gas, particularly in the electric and industrial sectors. A combination of forces, including deregulation of the utility industry and environmental concerns, could further expand gas demand. According to the Energy Information Administration's Annual Energy Outlook 2002, natural gas consumption for electricity generation (excluding cogeneration) is projected to increase from 4.2 Tcf (trillion cubic feet) per year in 2000 to 10.3 Tcf per year in 2020, an average annual growth rate of 4.5 percent. This forecast is based on the expectation that, at least for the near term, nearly all future electric utility capacity additions in the United States will be fueled by natural gas. These and other factors have resulted in extremely volatile natural gas prices. Because of these factors, exploration, production, and delivery of natural gas are anticipated to remain key issues for the foreseeable future.

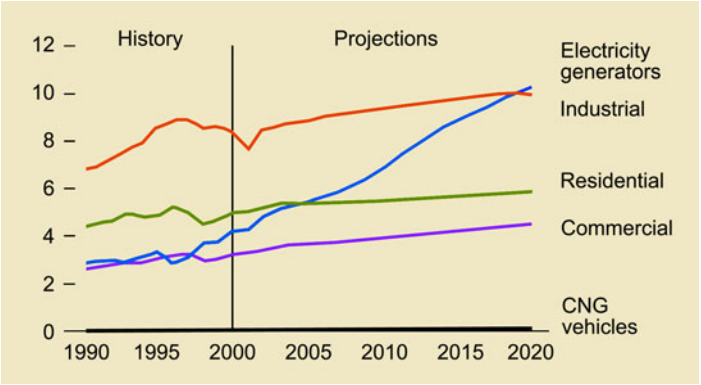
Substantial gas reserves exist that cannot be economically produced because they are located far from pipeline access or because they contain high levels of impurities. Also, there are substantial reserves in areas that are currently off-limits for production (e.g., moratorium areas and Federal lands). Technology is becoming more critical in the success of the gas industry, yet few organizations are willing to make the necessary R&D investments to ensure continued advancements.

Reliability of both the electric power grid and the natural gas distribution and transmission system is essential to the availability of affordable, clean energy for our Nation's homes, businesses, and industries. Refurbishment of existing infrastructure is key in some regions to ensure public safety. Gas storage capacity in certain regions is in short supply and will become more critical as demand increases and new use patterns based on distributed generation develop. Financing for new capital projects will be driven by price signals, but there may be a significant lag that could create transmission bottlenecks and stranded assets. Infrastructure constraints may stimulate innovative solutions in this technology area. Intense competition in the deregulated and restructured gas and electric industries is putting stresses on the existing infrastructure and threatening the reliability of our gas and electric systems.

Over the past several years, major energy companies have reduced overall RD&D spending and refocused their R&D portfolio on short-term activities. Reduced industrial RD&D adds to the Nation's uncertainty concerning future energy supplies. As noted above, by the year 2020, demand for natural gas is expected to grow significantly. Infrastructure stresses require relief by bolstering and expanding the existing system.

Others have recognized the need for a focused, Federal natural gas R&D program. The President's Committee of Advisors on Science and Technology (PCAST) has acknowledged that natural gas is a critical component of our Nation's energy future, and that appropriate action is required to assure its future availability. PCAST recognized gas as the "transition fuel of the 21st century," and recommended in 1995 that DOE develop a strategic R&D plan for natural gas.

In March 2001, the Department of Energy drafted a natural gas strategic plan. The initial version of this plan can be found at the NETL Web site (http://www.netl.doe.gov/scng).



Annual Energy Outlook 2002 [DOE/EIA-0383 (2002)]

4.1 Gas Exploration and Production

Our Nation is counting on expanded domestic natural gas supply and utilization to fuel our economy and protect our environment in the decades ahead. The Gas Exploration and Production program is focused on assuring the timely development of technologies needed to economically find and produce future supplies of natural gas in increasingly complex geologic settings.

Recent assessments of the Nation's natural gas resource base indicate that more than 1,400 Tcf of gas remain in the ground. Therefore, despite predictions that gas use could climb from 20 to 35 Tcf per year and beyond, there is general confidence that gas will remain a viable energy source for the foreseeable future. However, the many economic, environmental, and national security benefits of increased gas use will be realized only if this abundant resource can be converted to reserves (i.e., natural gas profitably producible at reasonable prices) at a pace necessary to support the growing demand.

Drilling Rig in Shallow Water

It is becoming increasingly necessary to drill into more complex, deeper, and lower quality reservoirs to meet rising demands for natural gas. One of the primary supplemental sources of gas will be "low-permeability" or "tight" reservoirs. Low-permeability reservoirs are known to contain vast quantities of gas across large areas in many of the Nation's natural gas basins. According to United States Geological Survey estimates, the Rocky Mountain region, for example, holds more than 6,800 Tcf of tight gas. However, given current costs and technologies, only about 100 Tcf (less than 2 percent) of this gas can be economically produced.

Our efforts are not only to define the quantities of gas that may be available to support future demand, but also to identify the technological barriers that must be overcome before these resources can be added to our reserves.

The NETL has a long history of working with the USGS, other Federal agencies, and the petroleum industry to uncover the potential of the country's marginal gas resources. Past work by DOE has been crucial in identifying natural gas reservoirs and enabling the production of natural gas from fractured shale, coal seams, and low-permeability sandstone. These "unconventional" resources, once considered to be "pie-in-the-sky" gas, now contribute nearly one quarter of our total domestic gas supply, and our reliance on them will continue to grow. Ongoing work in this area focuses on documenting the magnitude and potential of these resources in order to increase industry confidence and accelerate industry entry into these ventures.

New sources of energy will ultimately be required to fuel the Nation's energy needs. Methane hydrate, a solid substance formed when water freezes in the presence of methane, is one of the most promising of these fuel resources.

Methane hydrate occurs widely within sea floor sediments on continental shelves and below the permafrost in some onshore areas. Domestically this resource may be vast; some estimates suggest that as much as 200,000 Tcf of natural gas may exist in hydrate form. If only 1 percent of this volume can be recovered, 2,000 Tcf could be available. This amount would significantly expand our recoverable resources.

In contrast to their potentially great value as a natural gas resource, hydrates pose a significant hazard to conventional oil and gas-recovery operations. Drilling and production hazards, as well as sea floor stability issues, exist. If drilling and production activities cause methane hydrate to unexpectedly dissociate (i.e., revert to the original constituents, water and methane), there is potential for loss of drill rigs, production wells, and pipelines on the sea floor. It is also possible that dissociation may occur naturally, releasing large amounts of methane, a potent greenhouse gas.

Program Status

The Gas Exploration and Production program is developing advanced technologies to help ensure that adequate supplies of reasonably priced natural gas are available to meet expected future demand.

Gas Exploration and Production Program Areas

Program Area	Description
Resource Assessments	Quantifying the nature and potential of gas resources
Exploration Technologies	Enabling effective fracture detection
Drilling, Completion, and Stimulation	Reducing the costs and risks of extracting natural gas
Production Technologies	Maximizing recovery of gas from discovered fields
Gas Storage	Ensuring deliverability for tomorrow's high demand
Coal Mine Methane Utilization	Enabling production and use of methane from coal mines
Low-Quality Gas Upgrading	Removing impurities from gas reserves
Methane Hydrate	Exploring the next frontier in energy

The program supports the development of a steady stream of products and technologies that will progressively expand the Nation's recoverable resource base, provide continued lowering of production costs, and improve the efficiency of the gas storage system.

A key focus of the NETL's Resource and Reserve Assessments program is to preserve key gas industry data. As stewardship of America's marginal resources continues to change hands frequently through the sale and merger of different companies and their holdings, and with the growing prominence of small, independent producers, large volumes of valuable data including well logs, production data, and even location, are being lost. To address this problem, the NETL recently completed the compilation of a comprehensive set of gas reservoir data in a Gas Atlas Series and Gas Information System database.

The number of "conventional" reservoirs is finite, and it is becoming increasingly necessary to drill into more complex, deeper, and lower quality reservoirs to meet rising demands for natural gas. To address this issue, the Exploration Technologies for Low-Permeability Formations program pursues three activities:

- Testing and validation of unique and promising approaches in development settings.
- Verification tests of successful approaches in exploration settings.
- Transfer of the proven technologies to industry through repeated demonstration in a variety of regions.

A key focus of drilling R&D is to increase the overall efficiency of drilling operations as a key method of controlling costs. This can include longer lasting and more efficient bits, more accurate steering, and more efficient downhole monitoring. Deep drilling introduces significant additional challenges. To support the Nation's growing need to access natural gas in very deep settings (i.e., more than 15,000 feet of drilling depth), R&D sponsored by the SCNG investigates "smart" drilling strategies that can reduce rig downtime and overcome the problems of high temperatures, high pressures, and hard formations. However, simply "making a hole" more efficiently will not be enough; drilling, completion, and stimulation systems must be designed so that damage to the target formation is minimized. Therefore, the SCNG supports the increased use of underbalanced drilling systems that preserve reservoir productivity. Preparing a hole for production ("completion") means expensive and time-consuming efforts to line the hole with casing and then perforate the casing adjacent to the target formation. The SCNG sponsors a number of projects, such as casing-while-drilling, that may revolutionize this aspect of rig operations. Once the well is completed, it is stimulated to increase productivity. The use of common water and sand stimulation in shale-rich reservoirs, however, may unduly damage the formation. Therefore, the SCNG focuses on commercializing stimulation systems that use liquid carbon dioxide in place of water.

The success of a DOE-sponsored horizontal well drilled 3 miles deep into a dense sandstone formation in southwestern Wyoming has led to additional commercial drilling that could open up a potentially large, new supply of "non-conventional" natural gas in the Rocky Mountain region. Union Pacific Resources Company used fracture imaging and advanced drilling technologies developed by DOE and the Gas Technology Institute to drill a 17,000-foot-deep well with a 1,700-foot horizontal section. Production exceeded expectations, with more than 2.1 billion cubic feet of gas produced in the first six months. After 21 months of production, the well is still producing over 5 million cubic feet per day and will recover over 5 billion cubic feet of gas in the first 2 years. Based on the well's success, Union Pacific Resources Company is drilling two new horizontal wells into the same formation in the Greater Green River Basin.

A key component of ensuring future supplies of natural gas is the availability of production technologies that allow operators to produce more of the gas they have already discovered. Work aimed at maximizing recovery (i.e., the percentage of gas-in-place that is ultimately produced) focuses on:

- Designing wells and fields for maximum productivity.
- Extending the life of producing wells.
- Applying advanced technologies to the development of older fields to ensure that valuable national resources are not overlooked or left in-ground prematurely and therefore lost.

The NETL's efforts to maximize recovery of discovered reservoirs focus on two areas. The Secondary Gas Recovery program supports the application of new technologies in old fields to maximize ultimate gas recovery. The Stripper Gas Well Revitalization program specifically targets those wells where reversible well or formation damage has caused the production rate to prematurely decline to less than 60 Mcf per day.

In 1998, the NETL reinstituted its Methane Hydrate Research program, joining with other Federal agencies (USGS, Naval Research Laboratory, Minerals Management Service, National Science Foundation, and National Oceanic and Atmospheric Administration) to continue to address a series of critical questions concerning the chemical and physical properties of natural gas hydrates. A multi-year program plan, distributed to the research community in 1999, calls for initial laboratory studies to better understand hydrate properties, followed by field tests to study actual natural gas hydrate formations. In addition, the "Methane Hydrate Research and Development Act of 2000" was signed into law. This bill calls for the Secretary of Energy to commence a program of methane hydrate research and development.

Research into hydrate properties will eventually lead to the development of technologies needed to commercially produce methane from hydrates and address associated environmental and safety issues.

The objective of the methane hydrate program is to develop the knowledge and technology necessary to commercially produce methane from natural gas hydrates and address associated environmental and safety issues.

The program is designed to:

- Provide an accurate assessment of the location, quantity, and characteristics of methane hydrate.
- Develop the technology necessary to commercially produce natural gas from hydrates.
- Determine if and how methane hydrate affects sea floor stability.
- Determine the impact that methane hydrate has on the global environment.

Under the sponsorship of the NETL, the deep ocean research submersible ALVIN, with its three-person crew, made two dives in October 2000 to study and retrieve samples of methane hydrate from the Gulf of Mexico floor, some 6,000 feet below the surface.

(PHOTO CREDIT: ROD CATANACH, WOODS HOLE OCEANOGRAPHIC INSTITUTION)

Alvin Submersible

At the NETL, onsite researchers are investigating the formation and stability of hydrates in sediments, flow and thermal characteristics, and improved methods for mathematical simulation of gas recovery from hydrates. In addition, the NETL has developed and maintains an extensive methane hydrates Web site that is used by researchers all over the world to obtain the latest in hydrate R&D information.

The Low-quality Gas Upgrading subprogram focus is on improving technology needed to raise the quality of off-grade gas by removing the high levels of impurities found in roughly 41 percent of our natural gas proven reserves. The cost of upgrading can vary greatly, depending on volume, amount of impurities (nitrogen, hydrogen sulfide, carbon dioxide, water, etc.), presence of profitable higher hydrocarbons (ethane, propane, butane) that can be recovered to offset upgrading costs, and other factors.

The Coal Mine Methane Research and Development program was initiated in response to the Energy Policy Act of 1992, Section 1306, which identified work for "demonstrating commercial application of coalbed methane recovery which shall emphasize (1) gas enrichment technologies for enriching medium-quality methane recovered from coal mines to pipeline quality; (2) technologies to use mine ventilation air in nearby power generation facilities including gas turbines, internal combustion engines, or coal-fired power plants; (3) technologies for cofiring methane recovered from mines including methane from ventilation systems and degasification systems, together with coal in conventional or clean coal technology boilers; and (4) other technologies for producing and using methane from coal mines."

As part of the October 1993 *Climate Change Action Plan (CCAP)* and its goal of reducing greenhouse gas emissions, DOE, in conjunction with the Environmental Protection Agency (EPA), is supporting outreach, cost-shared demonstrations and market-entry projects to investigate and apply new, evolving, and existing technologies for capturing and utilizing methane emitted during coal mining.

Planned Activities

The purpose of the Natural Gas Exploration, Production and Storage program implemented at the NETL is to ensure that adequate supplies of reasonably priced natural gas are available to meet expected future demands. To achieve this goal, program planners strive to produce a balanced portfolio of R&D projects and timely issue/policy analyses.

In the near term (to 2005), the challenge is to maintain or reduce gas prices while sustaining high production rates. Therefore, the NETL supports R&D efforts that promise to:

- Reduce drilling costs through technologies that (1) increase rate of penetration, (2) provide long-lasting, multi-purpose bits, and (3) yield lighter drilling rigs.
- Enhance the efficiency of production from discovered reservoirs through advanced secondary gas recovery technologies, improved well planning, slimhole drilling, underbalanced drilling, and stripper well revitalization.
- Improve the deliverability of the Nation's gas storage system through enhanced reservoir management practices for conventional storage and upgrade the development of advanced storage concepts to support new, high-volume gas demands.

The mid-term (2005 to 2015) energy supply picture calls for continued rapid expansion of gas use that will depend heavily on full exploitation of the Nation's vast store of "unconventional" (marginally economic or high-risk) resources. Therefore, the Exploration and Production program contains R&D that will:

- Provide critical information on unconventional resource volumes and characteristics through assessment of the potential of the Nation's basin-centered and deep (located at depths greater than 15,000 ft) natural gas.
- Enable dramatic reductions in the cost and risk of deep drilling through improved, real-time, downhole telemetry systems and progressively higher pressure and higher temperature "measurement-while-drilling," "logging-while-drilling," and "casing-while-drilling" systems.
- Deliver advanced exploration technologies for improved "sweet-spot" detection in low-permeability reservoirs featuring a tested, integrated system for natural fracture detection, prediction, simulation, and characterization.
- Improve the economics of marginal projects through improved completion and stimulation systems and demonstration of the benefits of horizontal drilling in fractured reservoir settings.

Long-term (beyond 2015) gas supply is uncertain. However, it is clear that contributions from new sources for natural gas will be needed. The NETL is working on these issues now, with particular focus on:

- Extending the life of the current suite of resources under production by enabling ever deeper drilling and providing continual reductions in drilling costs.
- Enabling the production of gas hydrates by investigating (1) the occurrence and nature of methane hydrate, (2) sea floor stability, (3) the interaction between methane hydrate deposits and global climate concerns, and (4) the potential quantity of recoverable methane hydrate resources.

It is likely that production from domestic conventional gas reservoirs will peak sometime around 2010. With each subsequent year, domestic gas production will be increasingly reliant on the high-risk high-cost low-quality reservoirs within the remaining resource base. To convert these resources into reserves, dramatic reductions in risks and costs must be realized. Therefore, the Gas Exploration and Production program involves significant R&D focused on the mid-term that promises to:

- ***Reduce Drilling Costs***—Increased rate of penetration, multi-purpose, longer-lasting bits, and lighter drilling rigs.
- ***Enhance the Efficiency of Production from Discovered Reservoirs***—Advanced technology for locating bypassed zones, improved development well planning, slim-hole drilling, expanded underbalanced drilling, and improved practices for evaluating and revitalizing stripper (low-volume) wells.
- ***Provide Critical Information on Unconventional Resource Volumes and Characteristics***—Assessment of the distribution and potential of basin-centered gas and assessment of the Nation's deep resources (at depths greater than15,000 ft).
- ***Deliver Advanced Exploration Technologies for Improved "Sweet-Spot" Detection in Low-Permeability Reservoirs***—Integrated systems for natural fracture detection, prediction, and improved understanding of natural fracture characteristics.
- ***Increase the Productivity and Financial Performance of Unconventional Wells***—Improved completion and stimulation systems and expanded use of horizontal drilling in fractured reservoir settings.

The long-term ability of the domestic gas industry to supply needed volumes is far from assured. Most industry projections do not address this timeframe, but it is generally agreed that entirely new sources of gas must be developed to support continued gas demand past 2020. DOE is committed to pushing the envelope for gas use to 2050 and beyond, with particular focus on:

- Enabling dramatic reductions in the costs and risks of deep drilling.
- Identifying tomorrow's emerging gas reservoirs.
- Enabling the production of gas hydrates.

4.2 Gas Infrastructure Reliability

Reliability of natural gas distribution and transmission systems across the United States is essential to ensure the availability of clean, affordable energy for our homes, businesses, and industries. The projected increase in natural gas consumption will require maintaining much of the existing infrastructure while adding an estimated 38,000 miles of new transmission lines and 255,000 miles of new distribution lines. Given this scenario, it is clear that growth in demand will require a significant expansion of the existing infrastructure and considerable outlays of fiscal resources. The National Petroleum Council estimated that natural gas transmission and distribution companies would need to make capital investments of approximately $123 billion to meet new demand requirements through 2015.

Natural Gas Transmission Line in the Western United States

Several obstacles make it difficult for new demands to be met. They are the age of existing pipelines, an uncertain regulatory climate, the leadtime required for new pipeline construction, and a substantial capital investment. It is becoming clear that maintaining the integrity and efficiency of the existing gas infrastructure, and providing for needed expansion, may be among the most critical challenges to achieving substantial increases in gas deliverability.

Advances in materials, tools, and technologies will be needed to maintain the capacity of the current system and expand it for future demands. However, over the past decade, competitive forces in the deregulated gas industry have led to a decline in funding for R&D on natural gas transmission and distribution systems.

To accommodate the increase in natural gas consumption, the needed expansion of the natural gas infrastructure, and to increase energy security, the SCNG has set goals for the next 10 years that include:

- Develop remote monitoring technology to minimize third-party damage and increase security.
- Develop automated remote leak-detection devices to minimize leaks and enhance safety.
- Develop platforms, sensors, and repair technologies that allow rapid identification, analysis, and repair of pipe defects.
- Demonstrate next-generation instrumentation to accelerate automation and boost system efficiencies and capacities.
- Evolve existing technologies to more quickly impact reliability, integrity, and security.

Program Status

The gas infrastructure reliability program is working to ensure the reliability, flexibility, and safety of the domestic natural gas infrastructure system. The program works in conjunction with the private sector and other research laboratories to develop new technologies and practices needed to meet natural gas deliverability challenges.

A program to develop a wide range of innovations that could strengthen the reliability of the U.S. gas pipeline system was introduced in FY 2001. The new joint government-industry research program addresses critical technology needs in the Nation's natural gas infrastructure.

In May 2001, the Secretary of Energy announced the first-ever DOE natural gas infrastructure research projects. Eleven government-industry projects were awarded to develop high-tech approaches that improve the safety and performance of the Nation's pipeline network. Included in that array of innovations were new types of miniature robots and other sophisticated detection devices that pinpoint leaks or corrosion in pipelines. In one project, for example, researchers are developing an automated warning system to prevent nearby digging from damaging buried pipelines. In another project, investigators are studying how a natural pepper extract might prevent corrosion in a pipeline. Eight of DOE's national laboratories actively participate with private industry in developing these technologies.

In October 2001, DOE announced ten additional cost-shared projects focused on developing cutting-edge automation, new sensors and leak detectors, corrosion monitors, and other advanced devices that improve the way natural gas will be transported through tomorrow's transportation and delivery infrastructure.

The SCNG is also working closely with all sectors of the gas industry, from gas suppliers to end users, to identify operational factors that affect reliability.

Planned Activities

RD&D efforts are focused on maintaining and enhancing the high level of reliability U.S. consumers are accustomed to receiving. Future research will be initiated in four broad technology areas:

- Pipelines and distribution systems.
- Environmental protection.
- System integration.
- Gas storage.

With an aging natural gas infrastructure, special emphasis is placed on remote monitoring, inspection, and repair or replacement of existing pipelines. We are working with industry and others within DOE to review and update the roadmap for natural gas infrastructure activities and an R&D program designed to preserve the long-term security, safety, and reliability of our Nation's system.

4.3 Distributed Generation

To complement its work in improving the performance of intermediate- and large-scale power production, the SCNG is also focusing on technologies that will enable the further decentralization of power production. Most of the electricity consumed in the United States is produced in large central power plants. This power is then transmitted (with losses of up to 5 percent) to consumers via power lines. However, the ongoing restructuring and deregulation of the power industry, combined with recent technological advances, is providing many users with an alternative to centralized generation. Increasingly, businesses and industry are obtaining electricity from small modular power-generation units installed at their plant or factory. These "distributed generation" units can be designed and operated to efficiently meet each user's specific needs. Key to these efficiency gains is the potential for cogeneration, in which advanced gas-powered energy systems capture the waste heat from electricity generation through combined heat and power or combined cooling, heat, and power systems.

30-kW Capstone microturbine (box on left) and a 250-kW FuelCell Energy fuel cell in a fuel-cell, turbine hybrid configuration. This system accumulated over 6000 hours of operation and is suitable for DG applications.

Distributed generation has reached only the largest industrial facilities. To spread the benefits of distributed generation of electric power to smaller industries, businesses, and homes, technologies that provide for compact, ultraclean, efficient, quiet, and safe generation of electricity must be available and affordable.

Program Status

As a result of continued research and product improvement, fuel cell technology has shown a steady reduction in cost. The NETL sponsored development of phosphoric acid fuel cell (PAFC) technology at International Fuel Cells (IFC) in a project that was completed in 1993. As a result, IFC now markets onsite PAFC systems and has a manufacturing facility in Connecticut capable of producing fuel cell units totaling 40 MW of generation capacity per year. Over 220 PC25, 200-kW units are now in operation in the United States and around the world. Building the manufacturing base needed for commercialization of this early distributed generation technology was also fostered through the DOD "Climate Change Fuel Cell Program." This program offers rebates of up to $1,000 per kW for early installations through a grant program implemented largely by the NETL.

For fuel-cell distributed generation technology to compete effectively with other advanced technologies in the near-term distributed generation market, capital costs must be lowered to less than $1,500 per kW. The goal of the Near-Term Distributed Generation Fuel Cell program is to commercialize molten carbonate fuel cell (MCFC) and tubular solid oxide fuel cell (SOFC) technology by developing low-cost packaged modular fuel cell power generation systems. DOE, in conjunction with the Electric Power Research Institute (EPRI), the Gas Technology Institute, DOD, and several gas and electric utilities, has sponsored research, development, and demonstration of these advanced efficient high-temperature units in sizes up to 2 megawatts (electric). These technologies are expected to be ready for commercialization by 2003. DOE's emphasis is shifting toward much greater cost reduction and wider application through the new Solid State Energy Conversion Alliance (SECA) and Hybrids programs.

Siemens-Westinghouse 100-kW Cogeneration Solid Oxide Fuel Cell System

The world's longest running high-temperature fuel cell—a 100-kW unit that has helped validate the promise of a future, all-solid-state, combustionless source of electricity—successfully completed its planned test program. The Siemens Westinghouse Power Corporation, as part of DOE's advanced power technology program, built the pioneering "solid oxide fuel cell." Beginning operation in December 1997 at a Netherlands power station, the unit accumulated 20,000 hours of operation—proving that an all-ceramic fuel cell, a revolutionary concept, is rugged and reliable enough for future commercial power generation. Based largely on the success of the Netherlands unit, larger solid oxide fuel cells are now being designed and tested.

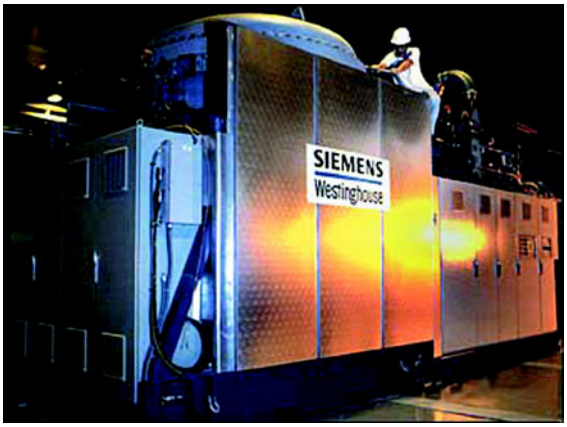
SECA is DOE's initiative for making fuel cells widely affordable, with a cost target of $400 per kW. This alliance brings industry, national laboratories, and universities together to develop high-power-density, low-cost solid-state fuel cells.

The Solid State Energy Conversion Alliance (SECA) and the efforts to develop fuel-cell, turbine hybrid systems are designed to make fuel cells widely available in the future.

The coupling of fuel cells and turbines to create hybrid systems further increases efficiency (compared to fuel-cell-only systems) and offers a promise of lower costs. Hybrid fuel-cell systems combine fuel cells with gas turbine engines, steam turbines, or even reciprocating engines. Hybrid systems will have efficiencies on the order of 60 percent initially with the potential to ultimately achieve 80 percent efficiency. Electricity cost should be 10 to 20 percent below that available from today's comparably sized power plants.

Fuel cells and fuel-cell, turbine hybrids are systems with very high efficiencies and very low emissions. These systems are well-suited for applications where power generation is sited close to the end-use customer. High-grade waste heat from fuel-cell systems is perfect for use in commercial, industrial, and residential applications, including heating and air-conditioning. When byproduct heat is used, the total energy efficiency approaches 85 percent.

The Siemens-Westinghouse 220-kW power system, the latest innovation in the DOE's fuel cell research program, is an innovative "hybrid" configuration. The new power plant, the first in the world to combine a state-of-the-art fuel cell with a gas turbine, is one of the cleanest and most efficient ways to produce electricity. Its success could help usher in a new option for the world's electric power industry—a source of power that would not require combustion. The world needs cleaner, more efficient ways to generate electricity, and this technology will help meet that need. This first-of-a-kind fuel cell is the product of a government-industry partnership that began almost three decades ago. That partnership is now paying off with a new technology that is unsurpassed in its environmental and power efficiency potential.



220-kW Siemens-Westinghouse Pressurized Hybrid Solid-Oxide-Fuel-Cell, Gas Turbine System Prior to Shipment to the National Fuel Cell Research Center at the University of California at Irvine

Planned Activities

The SCNG is working to develop various small and modular gas-fueled systems such as microturbines, reciprocating engines, and fuel cells. Work is also underway to explore designs that combine fuel cells and advanced gas turbines into hybrid systems that achieve unprecedented efficiency with ultralow pollution. In addition, the SCNG is working to test the potential of various novel approaches to electricity generation, including designs derived from supersonic aircraft engines.

An integral part of the SCNG's program in expanding gas use is research into the fundamental issues of materials, combustion, sensors, controls, and computer modeling to enable future breakthroughs in gas-utilization technology cost and performance. Much of this work is directed at providing the equipment and materials necessary to operate tomorrow's complex, integrated high-performance power systems. The SCNG conducts this research at onsite facilities as well as through a consortium of industry and academic partners.

4.4 Advanced Turbines and Engines

DOE predicts the United States will need up to 300 gigawatts (GW) of natural-gas-fueled turbine generating capacity by 2020. To serve the growing global need for electricity, turbine power systems will provide efficient generation options for use with both natural gas and clean coal technologies. As the world continues to need additional sources of new electricity, environmental demands on the power industry have continued to escalate. In the future, emissions-free turbine plants will be required to meet this growing need for clean energy. The Advanced Turbines and Engines product line consists of several subproducts designed to develop technologies that will assist in meeting the Nation's future electricity needs. These subproducts include:

- ***Advanced Turbine Systems*** to develop the most advanced gas-turbine combined-cycle technology.
- ***Advanced Reciprocating Engine Systems*** to develop natural-gas-fueled reciprocating engines for distributed generation.
- ***Highly Efficient Fossil Power Plants*** that combine turbines and fuel cells to achieve systems with efficiencies in excess of 70 percent.
- ***High-Efficiency Engines and Turbines program*** to establish the technology base needed to develop advanced turbines and engine modules for 21st century energy plants.
- ***Vision 21 Systems*** to develop technology modules for ultraclean 21st century energy plants using multiple fuels.

General Electric's newest *H System*™ gas turbine, the most advanced combustion turbine in the world, will be the first gas turbine to top the 60 percent efficiency threshold—the "four-minute mile" of turbine technology. The *H System*™ turbine will produce the least amount of carbon dioxide per kilowatt of electricity of any gas turbine available today. When deployed commercially, it will make a significant contribution toward reducing greenhouse gases. The machine, the size of a large locomotive, is the product of a jointly funded development effort between GE Power Systems and DOE. "Gas turbines will be the clear choice for the next wave of power plant construction. The new technology developed and manufactured here in Greenville will be at the crest of that wave," said Senator Ernest Hollings. "By keeping the 'Made-in-America' stamp on the world's most sophisticated power turbine, we will keep jobs in America and in South Carolina."

General Electric *"H System"* Gas Turbine Undergoing Assembly in GE's Factory in Greenville, South Carolina

Bright Light Award

The NETL was awarded one of only five prestigious ***Bright Light Awards*** presented in January 2001 by DOE to national laboratories for excellence in scientific achievements. The award recognizes the NETL's Advanced Turbine System (ATS) program as one of the department's five most consumer-oriented innovations developed since 1999. "The discoveries we honor today demonstrate our commitment to save consumers money and improve their quality of life," said DOE's then-Deputy Secretary. "The work being done by Energy Department scientists across the county should serve as an inspiring example of how public investment in innovation is making a difference in our lives."

Program Status

The Advanced Turbines and Engines program fostered the development of the most efficient gas-turbine combined-cycle systems ever produced (achieving efficiencies greater than 60 percent). Some significant accomplishments in this program include the following:

Faster and More Accurate Combustion Codes for Gas Turbine Simulations

Traditionally, combustion chemistry codes for predicting flue gas emissions require long run times and are often inaccurate. A code recently released by an NETL contractor provides predictions with excellent comparison to field data for nitric oxide (NO) and carbon monoxide (CO) emissions, and runs using this computer model can be completed 40 times faster than with existing codes. This new algorithm has been incorporated into combustor models used by Rolls Royce.

Active Combustion Control Technology

The NETL's research programs address various instabilities that occur in low-NO_x turbine combustors. Combustion instabilities produce a type of noise in the combustor that is associated with potentially damaging vibration and fatigue. Instabilities are a recognized barrier to fuel-flexible, low-emissions gas-turbine power generation. Onsite researchers at the NETL have successfully demonstrated an active control system that completely eliminates a certain type of instability in a gas turbine engine. Georgia Tech has developed an active control "smart injector" to overcome another type of instability. Testing of the smart injector on a turbine combustor resulted in a fourfold reduction in pressure oscillation.

Understanding of the Scientific Basis for Mist Cooling of Turbine Blades

Two major gas turbine manufacturers for heavy-frame ATS engines have adopted closed-loop steam cooling, which eliminates film cooling. Adding a mist to the steam significantly enhances cooling (100- to 200-percent improvements were observed). This will lead to longer component life and allow higher firing temperatures.

Improved Thermal Barrier Coating Life Extension Techniques

The use of thermal barrier coatings in gas turbines has been impeded by a lack of consistency in manufacturing and an inability to measure and predict their useful life. To avoid costly premature equipment failure caused by poor coatings, the University of Connecticut and the University of California, Santa Barbara, have developed non-destructive evaluation procedures. Laser fluorescence signals and modeling approaches are being used to determine the remaining useful life of thermal barrier coatings. The University of Connecticut is using their findings to develop a portable, low-cost, non-destructive evaluation instrument.

Creation of a Center of Excellence for Testing Distributed Generation Power Systems

To meet an industry need, a Center of Excellence, developed at no cost to DOE by the South Carolina Institute for Energy Studies, is now available to universities to test distributed generation equipment. The heart of this development is the Energy Systems Laboratory containing a 4-MW Solar Mercury Turbine (an ATS engine). Soon to be added are Capstone microturbines and the Asea Brown Boveri Virtual Utility Program—a procedure for monitoring and remotely controlling distributed generation power systems.

The NETL received the "Project of the Year" award from Power Engineering magazine at the Power-Gen Conference in December 2001 for the Advanced Turbines Systems program. This is the first time an Energy Department R&D activity has won this award. The award cites a joint government-industry development effort that began in 1992 and culminated recently in the commercial introduction of a new generation of advanced utility turbine systems. The new turbines broke through performance barriers that many in the power industry believed to be unattainable when the program began.

The Gas Energy System Dynamics Focus Area at the NETL provides the scientific basis for new, advanced turbine and distributed generation technologies. Higher efficiencies are needed because they not only extend projected supplies of natural gas, but also reduce CO_2 emissions from natural gas utilization. The efforts of Focus Area researchers to reduce pollutant emissions are aimed at nitrogen oxides. Nitrogen oxides are of primary concern from the combustion of natural gas because they contribute to the formation of ground-level ozone and are subject to stringent emissions limits.

The mission of the Gas Energy System Dynamics Focus Area is to improve our understanding of dynamic phenomena and operations in gaseous-fueled power generation systems. This Focus Area addresses the scientific issues in gas combustion science, gas conversion, and the dynamics of complex coupled systems.

The NETL has a distinguished history in natural gas technology development, especially in gas turbines, fuel cells, and novel combustors. Onsite researchers have played a key role in technology development by providing insights to the fundamental mechanisms of gas combustion and conversion under the dynamic operating conditions present in advanced gas turbines and fuel cells. The NETL is recognized internationally for work in the area of combustion dynamics and control strategies.

The Focus Area addresses scientific issues in gas combustion science, gas conversion, and the dynamics of complex coupled systems. Our partners include stakeholders from a broad array of universities, national laboratories, other Federal agencies (including the military), and turbine and fuel cell manufacturers.

The Focus Area conducts research in the following technology challenge areas:

- ***Improvements in Combustion Stability***—Turbine combustion stability can be degraded when engines are designed and operated in very-low-emissions modes. A universal path to dynamic stability has not been discovered, and static stability improvement is needed for ultraclean engines. The Focus Area conducts research on active and passive methods to improve combustion stability in conjunction with DOD and National Aeronautics and Space Administration (NASA) laboratories.

- ***Characterization of Low-Emissions Combustion Phenomena***—Because of unknown turbulence-chemistry interactions, and a lack of realistic data on high-pressure combustion conditions, low-pollutant-emission combustion phenomena are poorly understood. Better methods are needed to monitor hot sections of gas turbines. The Focus Area is positioned with its high-pressure, bench-scale facilities to partner with flame diagnostic experts at the Sandia-Livermore Laboratory to record this type of data, and use it to develop new combustion design strategies. The Focus Area also investigates novel hot section sensors and controls.

- ***Investigation of Novel Ignition Systems***—The efficiency of reciprocating engines is constrained by emissions and operational limits. High-efficiency operations can produce high nitrogen oxide emissions and are limited by ignition-system durability. The Focus Area investigates novel laser-ignition systems and control strategies for reciprocating engines.

- ***Methods to Monitor and Control Reacting Flows***—In the past, combustors, fuel cells, and engines had few control systems and were optimized for single operating conditions. Increasingly strict emissions or efficiency constraints, and diverse fuel capability require new control and optimization strategies and equipment. The Focus Area investigates application of new technologies, such as microelectronics, wireless controls, embedded micro-electrical mechanical valves, flame ionization chemistry, and aero-acoustics.

- ***New Strategies for Energy Conversion***—The Focus Area will investigate several candidate combustors that use fundamentally different strategies for reacting fuel and air. For example, a new approach called "trapped-vortex" will be investigated to stabilize ultralow-emission combustion. Pollutant formation may potentially be reduced, as the radical species populations will be distinctly different in such combustors.

- ***Analysis and Control of Non-Linear Coupled Systems***—Hybrid energy systems are expected to combine vastly different engine technologies such as gas turbines and fuel cells. Controlling the coupled system will present a significant challenge. Working with the Computational Energy Science Focus Area, the NETL develops science-based dynamic models for fuel cells and for coupled fuel-cell, gas-turbine systems, and uses these models to investigate control strategies. A partnership with the National Fuel Cell Research Center at the University of California at Irvine will result in software to evaluate hybrid systems.

Planned Activities

The High-Efficiency Engines and Turbines (HEET) program is key to achieving the National Energy Policy goal of making clean coal competitive so that it can be a secure, reliable, and affordable source of electricity. The turbine manufacturers in a deregulated power-generation market have sufficient incentive to meet current demand with their existing line of turbines for gas-based generation. But they are not developing fuel-flexible turbines for the future that can run on coal, because this is a long-term, high-risk effort that will not be pursued without government assistance.

Stakeholders (the power-generation industry, energy service companies, manufacturers and suppliers of gas turbine and engine power generation equipment, the research community, and State energy offices) have expressed concerns about the need for government support to develop high-efficiency engines and turbines. DOE has met and conducted workshops with industry and other government agencies. There is strong industry-government consensus that the HEET program can resolve the technical issues that limit the development of advanced turbines and engines.

The HEET program is designed to address government and industry needs and priorities; investment in this technology will result in substantial public benefits. It uses science and technology to advance fundamental knowledge and enhance our country's economic competitiveness by building partnerships with the private sector. The program R&D portfolio comprises four elements:

- ***Advanced Systems Analysis*** will be performed to evaluate new, promising concepts such as hydraulic compression or advanced cycles.

- ***Simple/Combined Cycle Development*** will include research and development in the areas of syngas combustion, durable materials, condition monitoring, design tools, aero-thermal technology, technology integration, and multi-megawatt demonstration.

- ***Hybrid Cycle Development*** integrates the Office of Fossil Energy HEET and Fuel Cell programs and contains four work areas: Advanced Hybrid Concepts, Hybrid Industry Teams, Hybrid Core Teams, and Vision 21 Coal-Fired Demonstration. The specific program objective is to achieve the required cost reductions by combining HEET turbines with fuel cell product line resources.

- ***Technology Base Development*** is performed in key R&D areas, such as combustion and low-emissions technologies, materials, advanced computing, and condition monitoring.

The strategy for meeting HEET goals and accomplishing projects within these four elements is to perform R&D in five major technology development areas: materials, combustion, aero-thermodynamics, instrumentation/condition monitoring, and design tools. The focus of the program is on technology development and infusion into advanced power systems to achieve the goals of DOE and other government programs, such as the DOE Office of Fossil Energy (FE) Vision 21 and fuel cell programs, and the Clean Coal Power Initiative. Several projects already underway will continue under the HEET program.

This program is managed by the SCNG and coordinated with the Office of Coal and Environmental Systems, both located at the NETL. The SCNG sponsors joint workshops and feasibility studies to coordinate and plan the HEET program. This coordination with industrial partners, other government agencies, and stakeholders is an ongoing task and will continue throughout the program.

New alliances have been forged for collaborative R&D with other Federal Government agencies (DoD, NASA), State Government agencies such as the California Energy Commission, and with the European Union. The Turbine Engine Alliance comprises DOE, DoD, and NASA, with the FAA soon to join. The alliance constructively coordinates turbine R&D within the three agencies, identifying technology needs and possible overlapping technology areas.

The American public and our Nation's turbine industry will benefit from the HEET program through the technology that is created. The program will yield environmental and cost-saving benefits for the American consumer: lower energy consumption and fuel-cost savings, electricity-cost savings, emissions reduction, system reliability, job creation, and conservation of land and water resources.

The objectives of the NETL turbine and engines programs are to:

- Complete full-scale no-load tests of prototype ATS engines and acquire validation data from host site demonstrations.

- Collaborate with industrial partners to integrate ATS into advanced coal-fired cycles, such as IGCC, pressurized fluidized-bed combustion, and high-performance power systems.

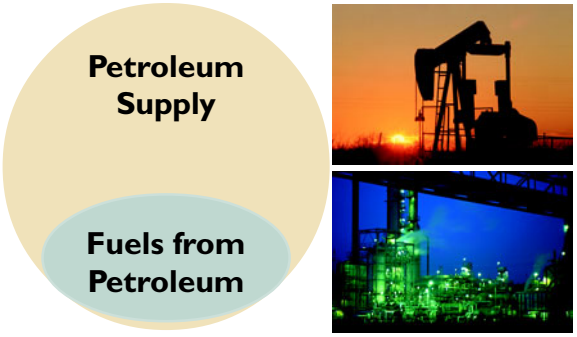
- Identify system design configurations to optimally integrate a turbine with a fuel cell for high-efficiency hybrid cycles.

- Consistent with the program elements described above, develop high-efficiency engines and turbines, focusing on five major technology development areas.

5 Petroleum Technology Program

The availability of an affordable and reliable fuel supply in the United States is essential for sustaining economic growth, social stability, and public health. However, there are several major concerns now facing the fuels industry and, consequently, the Nation. These include:

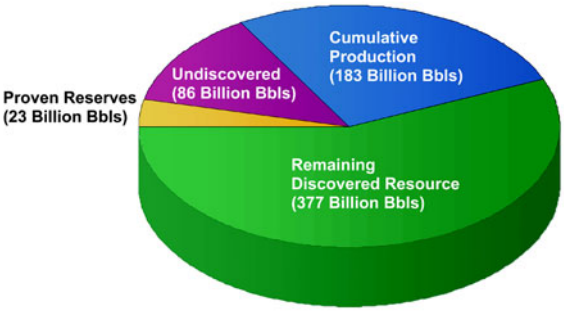
- Domestic crude oil production continues to decline and imports continue to rise, which impacts U.S. fuel security and balance of payments.
- Refining capacity is inadequate to handle increasingly heavy crude oil and meet projected future demands.
- New environmental regulations affect all aspects of the industry, from Federal land access to fuel specifications.



- Proliferation of locally mandated fuel specifications is making fuel transportation and distribution more complex, with potential impact on product integrity, supply, reliability, and cost.
- The fuels industry is changing—there has been a significant decline in private sector investment in mid- to longer term R&D.

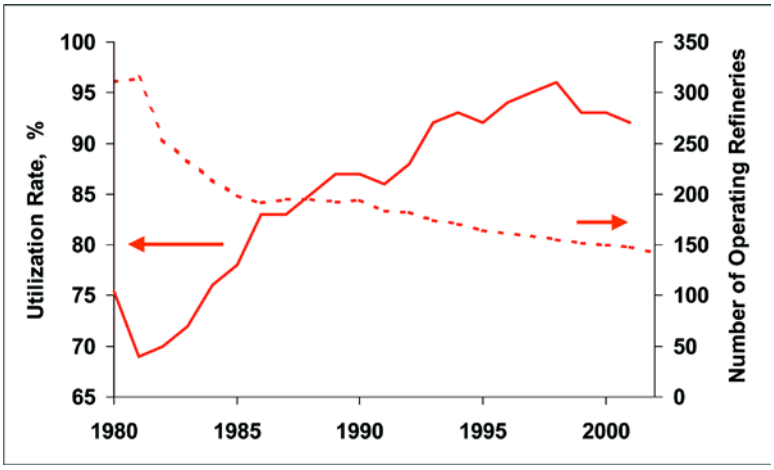
New and increased supplies of domestic oil are critical to meet our growing demand for energy. If we are to meet rising demands for petroleum without higher import levels, the United States must increase production, with much of this increase coming from previously undeveloped areas. Unfortunately, significant domestic resources exist in environmentally sensitive areas and offshore. Access to many of the oil resources in these areas is restricted because of concern for the environment and aesthetics as well as perceived conflicts with other uses of the land. To meet demands for increased production, application of practices employed in other pristine areas and further pioneering research to develop technologies that permit production without disturbing the environment will be required.

The United States is a mature oil-producing region. Our domestic petroleum resource base is over 350 billion barrels. At least two-thirds of the Nation's oil resources remain in the ground after production by conventional methods. In addition, the oil industry has significantly reduced RD&D projects applicable to domestic production while increasing emphasis on overseas opportunities. It is estimated that by 2010 more than 70 percent of our domestic petroleum resource will be abandoned. However, a large portion of this resource is amenable to recovery using advanced technologies.



Oil provides 38 percent of U.S. energy consumption and 96 percent of our transportation fuels. By 2020, it is projected that 67 percent of the petroleum used in the United States will be imported, and we will be importing more finished petroleum products than we do today. In the future, as the world's developing economies grow stronger, the demand for oil will increase, as will the value of remaining U.S. oil resources. Existing wells amenable to economic methods for enhanced oil recovery will help cushion deficits to the U.S. balance of trade created by oil imports. Preserving U.S. production capacity is critically important. As the second largest oil producing country in the world, the United States is in a position to significantly impact world oil price—the spikes in gasoline prices to more than $1.50 per gallon were driven by less than a 5 percent decrease in world oil production.

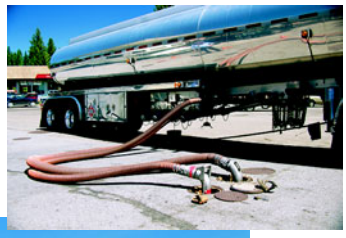
Petroleum refining is a capital-intensive industry. Over the last decade, 50 U.S. refineries closed. The last new U.S. refinery was built in 1978. With increasingly stringent environmental standards expected to apply across the entire liquid-fuel product slate, environmental permitting for increasing capacity at existing and new facilities is of major concern. Recent additions to U.S. refinery capacity have occurred exclusively through expansion of existing facilities (stretch capacity), with no construction of new facilities.



The gap between refinery capacity and utilization has been significantly decreasing. With refineries currently running at greater than 91 percent capacity, the ability of the Nation to respond to liquid fuels contingencies may very well have been compromised. These and other considerations are outlined in the National Petroleum Council's June 2000 Report, U.S. Petroleum Refining: Assuring the Adequacy and Affordability of Cleaner Fuels and the EIA Annual Energy Report 2002 (for year 2001).

Environmental regulations are impacting all aspects of the industry, including exploration and production practices, refinery emissions, and product specifications. The American public continues to demand superior environmental performance in the production, processing, and utilization of liquid fuels. This is of particular concern to the transportation sector, which accounts for 25 percent of our total energy use. The transportation sector is the largest U.S. source of CO, NO_x, and volatile-organic-compound (VOC) emissions. Petroleum use also contributes 43 percent of the Nation's carbon dioxide emissions, making it the largest U.S. source. All forecasts project dramatic increases in vehicle numbers and mileage traveled. And, to compound the situation, today's petroleum is heavier and contains more sulfur and metallic contaminants then at any other time in history.

The domestic petroleum business model is changing. Independent producers are playing an increasingly important role. Independent producers, who lack R&D capabilities, now operate the majority of U.S. wells, and drill 85 percent of all new wells onshore and 60 percent of all new Gulf of Mexico wells. The global business model is changing also. National oil companies are becoming international. The market has become increasingly competitive, showing a rise in super-majors and large independents leading to the formation of alliances. Competition and a historically low return-on-investment have curtailed capital investment and long-term R&D.



The NETL Petroleum Technology program addresses these issues through RD&D designed to develop technology that will ensure the availability of reasonably priced liquid fuels for transportation and other end-uses. The availability of competitively priced, domestically produced fuels supports a strong U.S. economy and helps strengthen the competitive position of the U.S. energy industry in global markets.

Five research areas constitute DOE's Petroleum Technology program: three in Oil Exploration and Production (Subsurface Imaging, Resource Development Mechanics, and Improved Recovery Methods) (section 5.1); Environmental Solutions (section 5.2); and Petroleum Fuels (section 5.3). Although each research area inherently improves environmental performance in the broad sense, the Environmental Solutions area provides specific applications that can be used industry-wide. The Exploration and Production areas have common program elements for field applications, demonstrations, and programs with independent producers.

5.1 Petroleum Exploration and Production

Historic and projected sources of petroleum for our Nation are well known, as are the end-uses of refinery products. Though two-thirds of petroleum is used in the transportation sector, other end-uses (e.g., residential home heating oil) are also important.

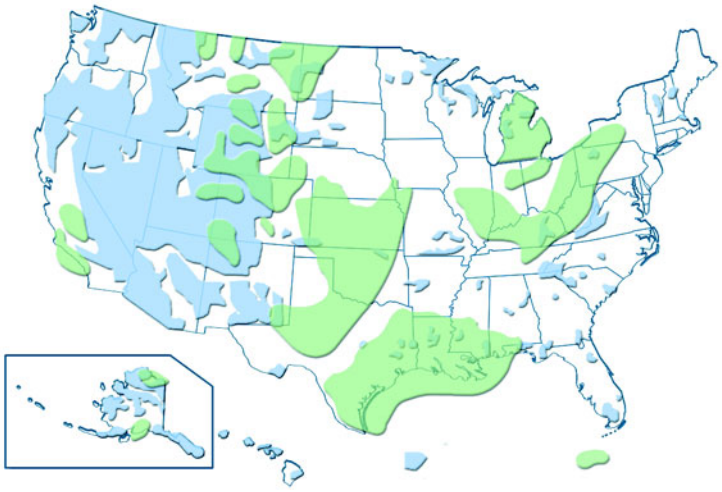
The ever-increasing quantity (and percentage) of petroleum imports, most from less-secure regions of the world, poses major risks to our national security and economic well being. Today, imports of crude oil and refined products make up over 56 percent of our total petroleum use. This is significantly higher than during the energy crises of the 1970s. Without alternatives, DOE projects that these imports will exceed 67 percent of our petroleum needs by 2020.

The NETL recognizes the need to make the United States less vulnerable to international energy crises and petroleum shortages and to improve the environmental performance of every component in the liquid fuels production, processing, delivery, and utilization chain. Consequently, the NETL has developed partnerships with other government agencies and all elements of the petroleum industries, including producers and technology developers, with emphasis on independent producers. In conjunction with these partners, the NETL has designed a RD&D program to address the issues that the fuels industry and our Nation face.

The goal of the Exploration and Production program is to promote the development and deployment of technologies that will find and produce more of the U.S. petroleum resource. The program addresses key technical and policy issues and has a special emphasis on deploying technology with independents.

Research areas in the Exploration and Production program (Subsurface Imaging, Resource Development Mechanics and Improved Recovery Methods) are focused to develop:

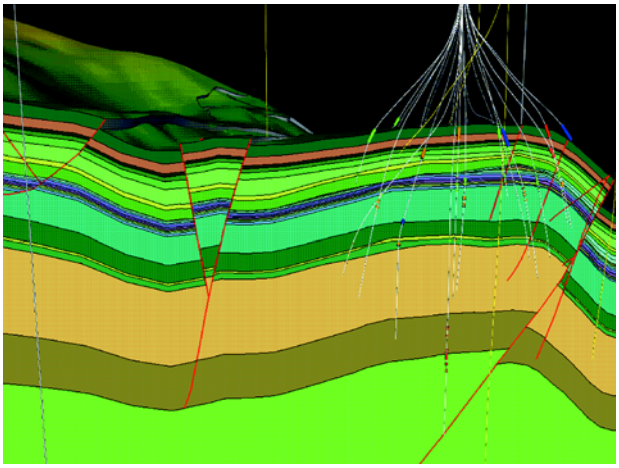
- Low-environmental-impact exploration technologies.
- Sophisticated seismic and other tools, enabling us to gather geologic data from deeper and more complex reservoirs.
- Tools and techniques to increase the resolution of geological imaging, process and interpret large data sets, and integrate all data into advanced models.
- Exploratory drilling without roads, almost no footprint, and small (tankable) amounts of drilling muds.
- "Smart systems" for reservoir drilling, development, and production operations.
- Technologies for improved petroleum production operating efficiency.
- Advanced technology for separating fluids and solids.



U.S. Reserves in Environmentally Sensitive Areas

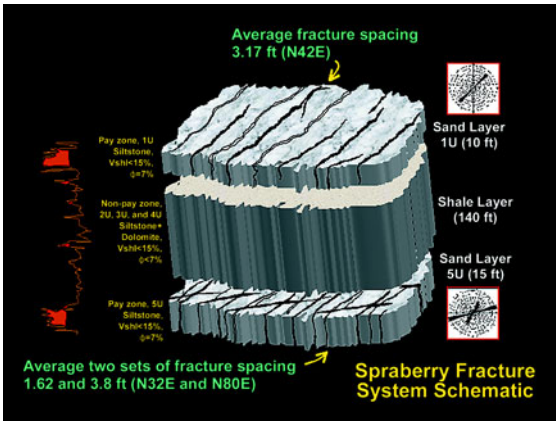
- Downhole and surface sensors for real-time production monitoring and control.
- Technologies that stabilize or reduce the oil and gas well abandonment rate.
- New technologies to enhance reservoir permeability for higher waterflooding efficiency and other displacement processes.
- Chemicals, such as those produced from biomass, for enhanced oil recovery at reduced cost.

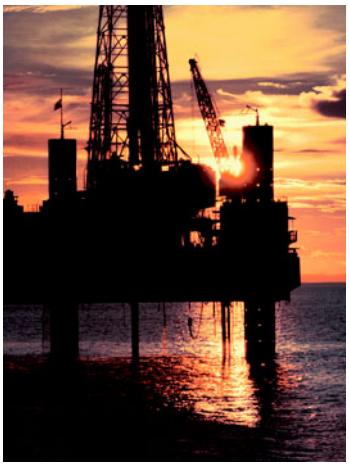
Program Status



The Subsurface Imaging research area plays an important role in advancing capabilities for reservoir characterization that affect various recovery, drilling, completion, and stimulation processes. For example, seismic technologies are geophysical techniques used to image oil reservoirs and the associated rock and fluids from the earth's surface and nearby wellbores. The application of improved seismic technologies in oil exploration and development has increased ultimate recovery volumes and reduced risk and costs by identifying barriers and pathways of fluid movement through the reservoir. The result is more effective targeting of well placement and improved management of enhanced oil recovery projects. Through the application of improved seismic technologies and increased efficiencies of operation, major oil companies have been able to reduce finding costs to $5 per barrel of oil equivalent. These cost reductions occurred between 1981 and 1994 from a starting point of $25 per barrel of oil equivalent for U.S. offshore operations and from $20 per barrel of oil equivalent for U.S. onshore and foreign operations. Finding costs have increased somewhat between 1994 and 1999 because of higher costs associated with Gulf of Mexico deepwater and subsalt activities, and because low oil prices have caused a downward revision in "booked" reserves.

Advanced Reservoir Characterization and Evaluation of Carbon Dioxide Gravity Drainage in the Naturally Fractured Spraberry Reservoir (Pioneer Natural Resources). Low recovery (< 10 percent of the original oil-in-place) from the Spraberry Trend reservoirs in the Permian Basin, West Texas, including marginally economic waterflood recovery, has marked this reservoir, that covers over one-half million acres with its 6 billion barrels of remaining oil-in-place, as a target for enhanced oil recovery. However, the fractured nature of the reservoir had precluded CO_2 flooding and resulted in a lack of confidence in the application of water injection. A DOE pilot project demonstrated that improved waterflooding techniques and CO_2 flooding at near miscible conditions combined with gravity drainage are viable means of significantly increased production from a naturally fractured reservoir. A pilot study indicated that an additional 5-8 percent of oil-in-place could be recovered by more efficient practices, increasing recoverable reserves in the Spraberry by 500 to 800 million barrels of oil. Oil production from the 70-acre pilot area increased from 200 b/d to 400 b/d. Cumulative incremental oil production after 1.5 years was over 75,000 barrels. Because of the positive results of improved waterflooding, leases are being produced.



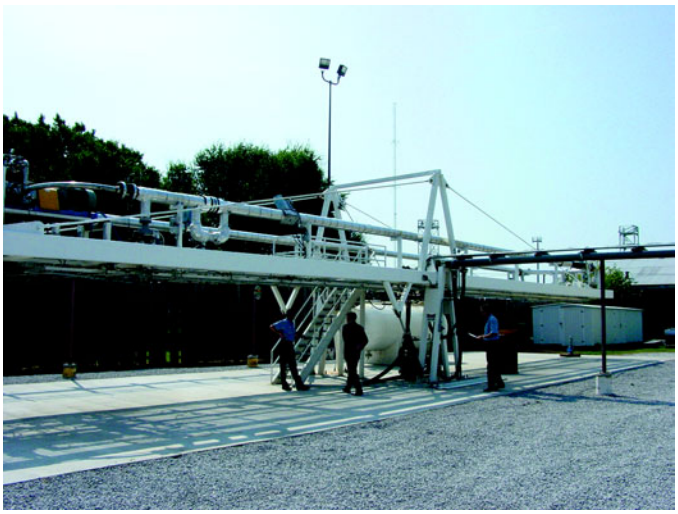


The Resource Development Mechanics research area is designed to reduce drilling and production costs, minimize formation damage, lower environmental risks, reduce surface footprint onshore and offshore, and improve access to culturally and environmentally sensitive areas. This program focuses on:

- Developing a series of long-term, innovative, or revolutionary systems described as enabling technologies.
- Developing innovative applications for offshore and ultradeep reserves in the Gulf of Mexico.
- Developing completion and stimulation technologies that respond to an industry-wide need (Petroleum Technology Transfer Council survey).

Without DOE participation, new technologies are usually accessible only to major oil companies because of the capital equipment expenditure required, perceived risk, or the proprietary nature of the technology. When a technology is first developed through the NETL's programs, whether by private or Federal researchers, it is available to the industry for immediate use. Subsequently, these new developments are licensed and made available for industry use by either a service company or the developing research laboratory. The Government continues to develop and improve the technology after its commercialization in an effort to increase efficiency and reduce the cost, thereby making innovative technology available to smaller producers and increasing the efficiency of the entire industry.

Paraffin Deposition Prediction for Improved Remediation (University of Tulsa). Paraffin (wax) deposition can be the determining factor for not producing deepwater fields, many of which are tied to nearby platforms with subsea flowlines. These remote facilities are vulnerable at low temperatures to deposition of paraffin in oil transmission lines. Paraffin deposition can lead to expensive, potentially catastrophic events in petroleum production. The cost of remediation necessitated by pipeline blockage from paraffin deposition is on the order of $200,000 per mile when the water depth is 300 feet, but on the order of $1,000,000 per mile when the remediation occurs in water depths near 1,200 feet.



DOE and a consortium of 36 companies funded development of a multiphase model that allows operators to optimize their piping designs, resulting in a significant reduction in investments as well as operating costs. The model resulted from (1) better knowledge of wax precipitation conditions and (2) development of a methodology to optimize crude production and transport parameters. This model is being used by industry as a basis for designing prevention and remediation techniques. Conoco used the technology in two projects in Indonesia, which resulted in a savings of $2 million in capital costs. Christian Mickelson Research, in conjunction with the University of Tulsa, has developed and successfully tested an ultrasonic device for measuring wax thickness in single-phase flow environments. An additional $1,890,000 in research funds has been committed by industry to make the model more robust.

The Improved Recovery Methods research area targets reservoirs that contain around 200 billion barrels of oil that are potentially recoverable by advanced methods. Although not the main focus of the program, assistance is also provided to independent producers in dealing with operational problems. This program includes research in the areas of chemical methods, gas flooding, microbial methods, heavy oil recovery, and reservoir simulation. Gas flooding and thermal heavy-oil-recovery technologies are producing more than 670,000 barrels a day in the United States (Enhanced Oil Recovery Report, Oil & Gas Journal, April 15, 2002).

One strategy of this program is to stop the high abandonment rate and permanent loss of U.S. petroleum resources. Since the oil industry has significantly reduced RD&D projects applicable to domestic production while increasing emphasis on overseas opportunities, the Government's role in developing methods for recovering this Nation's vast resource becomes even more important.

Independent producers operate the majority of U.S. wells, and many of those wells are economically marginal producers. In the lower 48 states, 22,000 independent operators drill 85 percent of all new wells, produce 50 percent of the oil and 65 percent of the natural gas. The independent segment of the U.S. petroleum industry contributes significantly to the production of domestic oil and gas resources, and thus contributes to minimize our Nation's dependence on imported oil.

Technology Development with Independents focuses on near-term (less than 2 years) field-oriented research projects conducted by small independents (fewer than 50 employees). Providing resources needed to test higher risk or unfamiliar technologies encourages technology innovation among independent operators. The goals sustain or increase current production levels and slow the premature abandonment of marginal wells and fields. A key success measure is the technology transfer element that ultimately leads to widespread application by independents.

Forty-eight field projects have been awarded since 1995 across a broad range of exploration, development and production technology areas. As of April 2002, 38 projects have been completed, and the rest are in progress. Three technologies have been commercialized: pre-formed gravel pack for sand production control, computer software to monitor stripper-well production, and application of multi-component vertical seismic profile technology.

Midway-Sunset Field Class Project (University of Utah, Arco Western Energy, AERA Energy). An abandoned Bakersfield, California, oil property (Pru Fee) was brought back to life in 1995 by a field demonstration project that has produced more than a million barrels of oil, once thought unrecoverable. This oil volume is more than half as much oil as the property produced in its first 80 years of operation. Because of the success, oil is now flowing from 100 new privately funded wells in the immediate vicinity. The advanced technologies demonstrated in the Federally cofunded field test could lead an estimated 80 million barrels of oil production. Federal taxes on this oil alone would total more $10 million, nearly five times the Government's original investment in the Pru Fee project.

Conformance Improvement Using Gels. The New Mexico Petroleum Recovery Research Center (NMPRRC) with support from DOE and a consortium of 20 industrial companies has pioneered advances in improving reservoir sweep efficiency, preventing fluid channeling through reservoirs, reducing saltwater production, controlling water and gas shutoff, and optimizing gel placement. This project concentrated on aspects of gel control of water flow in fractures, including developing gels that can reduce permeability to water more than that to oil or gas, and optimizing placement of blocking agents in reservoirs where channeling problems are caused by natural or hydraulically created fractures. During the 1990s, more than 2,000 gel treatments were applied using the principal gel studied in this project. These treatments were documented to reduce water production by over 500,000 b/d and increase oil production by over 8,000 b/d, as exemplified by three cases:

- ARCO's application of polymer gel technology developed in this project to decrease gas and water production and increase oil production in Prudhoe Bay Field, Alaska, resulted in the production of an additional 8,030,000 barrels of oil per year, yielding $40 million per year from 1995 to 1998. Water production was decreased by nearly 7 million barrels per year, a savings of nearly $3.5 million per year. The total economic benefit of the technology was over $218 million.

- Chevron's application of gel treatments in Rangely Field, Colorado, resulted in production of an additional 685,000 barrels of oil. The $4.2 million treatment cost was recovered in 8 months.

- A gel treatment by Phillips Petroleum Company of a well in Texas saved $33,000 in water disposal costs in 1995. Incremental oil production of six b/d generated $38,000, and reduced lifting costs and maintenance.

Planned Activities

An Offshore and Arctic Exploration and Production Initiative will develop and demonstrate technologies to more efficiently recover existing reserves and develop new resources. Technology areas to be included in the program are:

- Improved technologies to find and characterize oil resources.

- Imaging technologies and logging tools to lower costs.

- Improved drilling technologies for exploration and production.

- Improved production technologies.

- Safety issues dealing with hydrates, permafrost, and subsidence.

An Advanced Technologies with Independents Initiative will reduce field abandonment and stimulate independents to open and operate in previously abandoned or new areas including offshore. Technology areas will cover all aspects of exploration and production.

A Fundamental RD&D Initiative will develop longer term (7+ years) applied technologies for revolutionary improvements in exploration, drilling, or production. Advanced technologies for the domestic unconventional petroleum resource base will focus on development of an expandable, expendable, mono-microborehole.

5.2 Environmental Solutions

Saltwater Spill on Soil

Spill Site After Remediation

The Environmental Solutions program promotes petroleum-technology development that mitigates environmental risk posed by petroleum exploration, production, and refining while allowing optimum recovery and use of our Nation's resource. Specifically, this program element will:

- Promote environmental best management practices to enable industry to reduce compliance costs and improve environmental performance.
- Assist Federal and State Governments in making sound regulatory decisions based on scientific information and principles.
- Assess new risk-based approaches to environmental cleanup for existing domestic refinery grounds and petroleum production sites.
- Develop the next generation of advanced environmental cleanup technologies for refineries.
- Identify and evaluate means to effectively permit new refinery units in a timely and cost-effective manner.
- Study and evaluate advanced multimedia emissions approaches (air, liquid, and solid) to permitting new domestic refineries.
- Investigate biotechnology and other innovative processes to upgrade heavier crudes prior to refining.
- Raise public awareness and bring an energy policy perspective to oil and gas environmental issues.
- Increase industrial access to public lands and waters (location of more than 50 percent of the Nation's petroleum resource).
- Streamline permitting without compromising the environment.
- Develop residual oil upgrading and refining technologies to reduce air, water, and solid emissions.
- Develop scientific information on the environmental and health risks associated with the pollutants emitted by the petroleum industry.

Program Status

The Environmental Solutions program works with industry, government agencies and the public to allow petroleum-production activities to proceed in a risk-based scenario with buy-in from all stakeholders. A working group of Federal regulatory agencies responsible for overseeing compliance of the petroleum industry was organized by the NETL. The working group discussed the environmental regulatory constraints imposed on the industry to determine where technology innovation could affect access or production. The NETL works with the Petroleum Environmental Research Forum, an industry group dedicated to developing and sharing best technical practices, to develop guidelines acceptable to the EPA on end-points for compliance in studies titled "How Clean is Clean?" By providing scientific data, the NETL encourages policy and regulatory decisions that are sound, reasonable, and attainable.

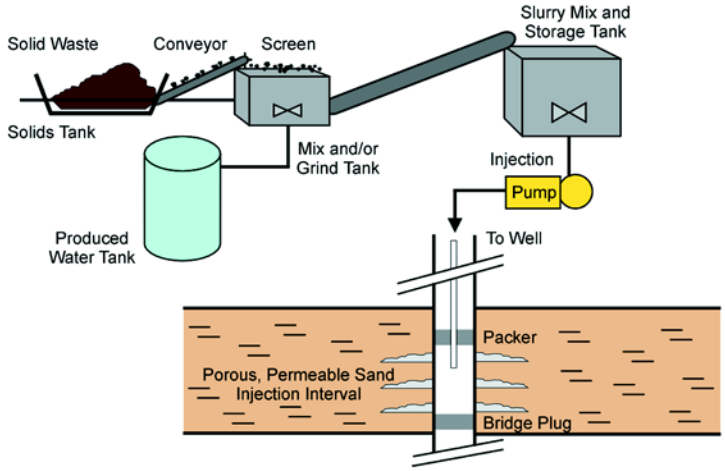
Several ongoing research activities involve analysis and modeling of air emissions, particularly $PM_{2.5}$ derived from fuel use and from industrial complexes such as petroleum refineries. DOE is partnering with several States to provide sound, science-based data for realistic compliance standards related to fine particulates. New sampling, analysis, and measurement technologies are being developed to determine potentially significant sources of emissions subject to the new Federal $PM_{2.5}$ air quality regulations for fine particulates.

Several project participants partner with industry to conduct work on advanced crude oil upgrading processes. Crude oils can be biochemically converted to lighter oils, thus reducing sulfur, trace metals, and nitrogen content. However, there are problems to be overcome before crude oil bioprocessing can be used commercially.

The benefits from Petroleum Environmental Solutions occur in all program areas. These benefits accrue as technologies are developed to lower barriers to the permitting process, to enable scientifically sound environmental regulations to be promulgated, and to foster risk-based decisions for cleanup end-points. Petroleum Environmental Solutions has saved $9 billion in environmental costs by improving permitting and risk-based decisionmaking. The expected future benefits of current activities are another $7 billion (National Energy Policy, Report of the National Energy Policy Development Group, May 2001). Other benefits of DOE's studies allow policy makers to make sound regulations based on scientific merit. Reducing the environmental footprint of exploration and production increases opportunities to produce oil from Federal resources, thereby decreasing U.S. reliance on imported oil.

Texas Electronic Compliance and Approval Process (ECAP) and Environmental Compliance Assistance System (ECAS). The ECAP and ECAS are examples of a DOE-funded product to streamline compliance with environmental oil and gas regulations. The ECAP system eliminates the need for the operator to supply information the Texas Railroad Commission (TRRC) already has on file in its databases. It includes a streamlined application process that can be completed online, the electronic payment of permit fees, and the capability to submit plat information in digital or scanned formats. This eliminates much of the editing required and reduces the need for filing corrected reports. An operator with an Internet connection can file anytime from anywhere, and costs of filing are greatly reduced. The processing and approvals are completed in less than half the time of that required for mailed applications. The costs for each permit filing have been reduced by over $200. If Texas operators use the completed online process for only 25 percent of the State's oil and gas permits, the economic benefits of ECAP in Texas could be $17 million annually.

The online Environmental Compliance Assistance System (ECAS) helps operators and managers of small oil and gas exploration-and-production companies understand their environmental compliance responsibilities. The ECAS Web site is designed for easy navigation and provides guidance through direct links to Federal and State regulatory agencies; help with water management plans, records management, emergency response, and remediation methods; and information on the latest Federal environmental requirements.



Improved Oilfield Waste Injection Techniques (Terralog Technologies). Disposal of large volumes of produced wastes from oil production operations is a major cost and a potential environment hazard. Oilfield wastes include produced sand, drilling muds, tank bottoms, and sludge remaining after oil has been produced, stored, and transported. Forming these wastes into a slurry and injecting this fluid mixture into formations has become an acceptable, environmentally approved method of disposal.

Terralog Technologies developed a cost-effective method to protect the environment while injecting oilfield waste into deep subsurface formations. Operating guidelines and best practices for disposal of large volumes of oilfield waste and effective monitoring of injection volumes were established. Louisiana has incorporated these guidelines into State environmental regulations with EPA approval. The California Division of Oil, Gas, and Geothermal Energy has informally adopted the guidelines for use in California slurry injection projects. Establishment of universal guidelines across the United States would decrease costs of disposal for the petroleum industry and improve environmental compliance.

Planned Activities

An Air and Water initiative will study methods for decreasing emissions from oil exploration and production operations. This work will involve technologies that will:

- Improve handling of produced waters from coalbed methane production.
- Improve separation of oil and water.
- Provide improvements in remediation efforts.

A Total Maximum Daily Load (TMDL) Initiative will improve models currently used to determine loading and responsibility for reducing emissions to achieve standards.

A Membrane Initiative uses technology developed under other Federal programs to separate critical gases in the refinery. This improves performance of reactors and allows better separation and recovery of waste streams.

New technologies will allow breakthrough processes for improving refinery emissions, especially for processing heavy crude oils. These include solid alkylation, bioprocessing of heavy crude oils to reduce the severity of refining while obtaining quality fuels, and science-based source identification of emissions.

5.3 Petroleum Fuels

The Petroleum Fuels program targets currently unmarketable resources by supporting the development of advanced gas upgrading and conversion processes to bring low-grade gas up to pipeline standards and to convert remote gas to more readily transportable, higher value liquid fuels and feedstocks. The program seeks to lower the still substantial costs of converting natural gas to liquid hydrocarbons and producing liquefied natural gas on a useful small scale. Consequently, most of the gas-to liquids (GTL) efforts are currently directed to improving the economics of converting methane to syngas (i.e., carbon monoxide and hydrogen), the intermediate products necessary for conversion to hydrocarbon liquids. Paraffinic liquids are easily made into environmentally desirable diesel fuels and other products.

Just as the President's "Freedom Car" initiative would require hydrogen, future engine systems will require special fuels or hydrogen. Hydrogen is predicted to emerge as the primary energy transfer medium of choice as applicable technologies are developed, perfected, and deployed. It is not yet clear how a transition to the so-called "hydrogen economy" will be achieved, but original hydrogen production will likely be from methane conversion.

Program Status

A three-phase effort for the development of a novel ceramic membrane reactor able to separate oxygen from air and partially oxidize natural gas to syngas in a single step has been the principal focus of this work. This "ionic transport membrane" will allow the use of pure oxygen to produce syngas while avoiding the expense of an air separation plant. Economic and process analyses have clearly indicated that a target reduction of 25 to 30 percent in capital cost is achievable.

The Petroleum Technology program has developed partnerships with other government agencies and all elements of the liquid fuels and transportation industries, fuel producers, technology developers, and engine and emission control manufacturers to address the issues that the fuels industry and our Nation face.

Slurry reactor technology has been identified as the most promising means of converting synthesis gas (carbon monoxide and hydrogen) to liquid fuels. This technology requires research to better understand reactor dynamics and to ensure efficient system performance. DOE's 35 barrel-per-day state-of-the-art slurry reactor system in LaPorte, Texas, evaluates a host of applications that have validated the basic and applied science and engineering associated with synthesis gas conversion.

The highly successful, on-going demonstration of Liquid Phase Methanol technology is the direct result of the tests performed at DOE's Alternative Fuels Development Unit (AFDU). The AFDU is the only operational unit in the world that is available to technology developers on a nonexclusive basis. The plant uses synthesis gas from a nearby facility as the reactant for producing a wide range of high-value products. The specific product slate is determined by (1) the hydrogen-to-carbon-monoxide ratio of the synthesis gas, (2) the reactor operating conditions, and (3) the catalyst used. Research at the AFDU is essential to the commercialization of U.S. advanced fuels and chemicals technologies based on synthesis gas conversion. It is imperative that the United States support a strong Government-industry-academia research partnership to develop clean fuels that improve the environment and diversify our resource base. The AFDU must continue to be available to technology developers who need to take the most promising results of the partnership's efforts and validate them at the proof-of-concept scale.

Planned Activities

Options for the use of natural gas produced in the Alaska North Slope region are being analyzed. The analysis shows that there are several practical alternatives for the use of this resource. Feasible alternatives include (1) shipment of liquid fuels produced using GTL technology to California, (2) delivery of natural gas by pipeline to various regions in the United States, and (3) shipment of liquefied natural gas to Japan.

6 Environmental Technology and Business Excellence

Surface contamination monitor deployed as part of an ASTD at Nevada test site

Five decades of nuclear weapons production and three decades of worldwide commercial nuclear power plant development (including research reactors) have resulted in a large amount of radioactive, chemical, and other waste materials that require cleanup, along with facilities to be deactivated and decommissioned. The NETL is a contributor to the mission of the Environmental Management program responsible for the cleanup of former DOE nuclear weapons sites across the country. We are a key resource in developing, funding, and managing research, development, demonstration, and deployment projects for the Science and Technology program within EM, with a major emphasis on fostering relationships with private sector organizations to secure cost-effective solutions to DOE's environmental cleanup problems. While much of this activity involves procurement and management of private-sector contracts, we also work cooperatively with DOE site contractors, national laboratories, and international organizations to provide technology-based solutions. In addition, the NETL directly supports policy decisions, best-management practices, acquisition planning, and cost-estimating practices through the Center for Acquisition and Business Excellence (CABE). The CABE has a proven track record with DOE clients and is a trusted and reliable partner that supports various programs to both EM's and DOE's benefit.

6.1 Environmental Management Science and Technology: Reducing Cost and Risk of Remediating DOE's Weapons Complex

The NETL supports the cleanup of DOE's Weapons Complex by implementing several extramural technology development and deployment programs for EM. The NETL contracts with industrial and academic organizations to develop environmental technologies to address cleanup requirements at DOE sites and conduct subsequent demonstration and deployment efforts within the DOE complex. We also work cooperatively with DOE site contractors, other national laboratories, and international organizations to provide technology-based solutions to aid environmental cleanup activities.

Program Status

The NETL manages a comprehensive national program addressing technical needs through applied R&D efforts, large-scale demonstration projects, and accelerated site-deployment projects to encourage the use of improved and innovative technologies and systems. The goals of the program are directly linked to EM's new science and technology thrusts to accelerate site closure and to develop alternative approaches to high-risk, high-cost baselines throughout the DOE complex. We seamlessly bring together the considerable knowledge and expertise of a diverse group of researchers and scientists to accomplish these goals.

The NETL provides the full range of services that are needed to develop innovative environmental technologies, from the development of a concept through full-scale demonstration, which leads to commercially available equipment, systems, or processes and services. The principal strategy is to foster strong and broad relationships with the private sector, Federal research facilities, and international organizations. The private sector includes large and small businesses, private research organizations, and colleges and universities. These organizations are full partners constituting a "virtual organization" with a unified goal of achieving stepwise improvements in terms of cost and risk reduction, and schedule acceleration for the cleanup of DOE's contaminated facilities and sites. The NETL's philosophy is to ensure that the best solutions are brought to bear on DOE's environmental-management problems, and that broad technology application also occurs within the commercial nuclear industry.

Goals for Industry Partnerships:

- Ensure the private sector is able to compete within the DOE market and deploy cost-effective solutions for environmental cleanup.
- Develop user community confidence and willingness to use innovative technology.
- Establish confidence in the private sector community that will bid for future DOE work, thus enhancing competition.

Significant contribution in the support of the nine EM goals/priorities established by the Assistant Secretary have been made through the development of a competitive private-sector supplier base to help reduce the cost and time required to complete the EM cleanup mission. Since 1992, the NETL has entered into over 145 R&D contracts with private sector entities on behalf of the EM Science and Technology program. Technologies proved to have significant advantage over baseline approaches often become candidates for a Large-Scale Demonstration and Deployment Project (LSDDP) or an Accelerated Site Technology Deployment (ASTD) project.

The NETL established the LSDDP as the primary mechanism to achieve its goal of widespread deployment of deactivation and decommissioning technologies. In an LSDDP, innovative technologies are demonstrated side-by-side with baseline technologies during actual deactivation and decommissioning operations. These demonstrations result in true comparisons where validated cost and performance data are collected for both the innovative and baseline technologies while operating under the same conditions. To date, 10 LSDDPs have been supported by the NETL; three are still active in FY 2002. These LSDDPs have resulted in the demonstration and subsequent deployment of 63 improved decontamination and decommissioning (D&D) technologies more than 320 times in DOE's deactivation and decommissioning projects.

ASTD projects provide EM sites an opportunity to leverage their project funding with science and technology funding to address specific problems with proven, yet oftentimes underutilized, technologies. The use of ASTD projects has proven to be another quite successful mechanism to assist EM closure sites in meeting their closure schedules safely and less expensively.

The following are examples of science and technology accomplishments supporting EM's two "new thrusts":

Assisting EM Site Closure

The NETL has made significant contributions to the Rocky Flats Closure Project, meeting or exceeding closure milestones through the Rocky Flats D&D Initiative (RFI) and a number of ASTD projects targeted at specific site problems. Because of its past mission, many of Rocky Flats' facilities and their associated processing equipment are contaminated with plutonium and other transuranic (TRU) elements. The primary objective is to safely reduce the amounts of TRU waste shipped to the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico, for disposal.

The RFI initially focused on installing a Centralized Size Reduction and Inter-Building Transportation System for size reduction of over 1,000 contaminated gloveboxes and miles of contaminated process piping and ductwork. Because of the success of alternative methods supported through the ASTD projects, this centralized system was deemed unnecessary. Through innovative decontamination processes and improved characterization methods to verify that decontamination objectives have been met, costly size reduction activities have been avoided, resulting in significant cost savings. Recent estimates by the Management and Integration contractor at Rocky Flats indicate life-cycle cost savings attributed to these ASTD projects at $256 million.

Rocky Flats Worker Disassembles a Lead Box in Building 771

Beryllium dust is a significant workplace hazard at Rocky Flats, and exposure can lead to chronic beryllium disease, an irreversible and sometimes fatal scarring of the lungs. Through an NETL contract, Science & Engineering Associates, Inc., is developing an innovative real-time monitor for surface and airborne beryllium. The portable beryllium

monitor will be applied to continuous air monitoring, field analysis of filters from personal air monitors, and analysis of surface wipe samples. The life-cycle cost savings from the beryllium monitor and other radiological sampling and monitoring systems deployed through an ASTD project at Rocky Flats is estimated at $100 million.

The NETL has been actively involved in assisting Ohio sites long before their designation as Closure Sites in 1998. In 1995, a LSDDP was initiated, which compared improved technologies against baseline technologies for the decontamination and demolition of Plant 1. This project demonstrated 13 improved technologies, 7 of which have been subsequently deployed at Fernald and other EM sites for a combined total of 70 deployments. The Personal Ice Cooling System (PICS) and Oxy-Gasoline Torch represent two particularly successful technologies that have now been used complex-wide. The success of these two technologies was in large part a result of ASTD project support, following demonstration and performance validation in the LSDDP.

ARCADIS Geraghty & Miller was awarded a contract in FY 2001 to develop a technology for in-situ chemical stabilization of metals and radionuclides through enhanced anaerobic reductive precipitation. This technology will provide benefit to Fernald closure activities by accelerating the completion of the groundwater pump and treat system so that it coincides with the rest of the site's 2006 closure milestones. The technology's approach is based on the fact that, as groundwater pollutants move through the subsurface, conditions can be optimized to cause beneficial chemical and physical transformations to occur, such as modifying the redox chemistry of the aquifer and irreversibly fixing the uranium contamination in place for geologic time periods.

The Pipe Explorer™ system, developed by Science & Engineering Associates, Inc., has had four closure site deployments. The most significant of these was the deployment at the Columbus Environmental Management Project's King Avenue and West Jefferson sites to characterize all suspect contaminated sewer lines. The Pipe Explorer™ system was used to differentiate between contaminated and non-contaminated pipe drain segments, allowing excavation of only those segments that were contaminated, saving the two sites $5.2 million.

Pipe Explorer™ at Argonne's CP-5 Facility

At Mound the NETL conducted an LSDDP for deactivation and decommissioning of surplus tritium facilities. This project provided a rare opportunity to identify and evaluate methods that improve worker safety while achieving cost savings and reducing schedule requirements. Sixteen innovative technologies were demonstrated to treat tritium waste and deactivate and decommission tritium-contaminated facilities and equipment. Many of these technologies are expected to provide significant benefits to other DOE sites. For example, Savannah River is investigating the use of NOCHAR Petrobond to treat 37,000 gallons of aqueous PUREX waste. Initial estimates indicate potential savings of more than $91 million.

The Well Injection Depth Extraction (WIDE) system, commercialized by Clean Technologies International Corporation, is being deployed at the Columbus Environmental Management Project's West Jefferson Facility. WIDE is an innovative in-situ remediation technology that utilizes prefabricated vertical wells to extract groundwater and soil vapor using an applied vacuum. The system is being deployed in conjunction with the Selective Separation Cartridges™, developed by 3M Corporation, to remove Cs-137 from the soil.

WIDE Application at Columbus—West Jefferson

Addressing High-Risk, High-Cost Problems

The NETL is committed to reducing the risks and costs associated with cleanup of DOE's contaminated excess facilities and sites by developing improved technologies and methods that accelerate deactivation and decommissioning. These efforts reduce or eliminate EM's surveillance and maintenance requirements, saving taxpayers billions of dollars. For example, we support the Hanford 2012 Vision to accelerate cleanup of the Hanford production reactors and restore more than 550 square kilometers of land along the Columbia River, making it available for other uses. In 1996, the NETL was at the forefront, providing support to Bechtel Hanford as they explored the viability of placing the first of nine production reactors into an Interim Safe Storage (ISS) condition. Through an LSDDP, Hanford demonstrated 20 improved and innovative technologies during ISS of the 105-C reactor. Sixteen of these technologies have since been deployed at Hanford or at other EM sites. ISS reduced the 105-C reactor footprint by 81 percent and saved an estimated $484 million. The approach has been approved as the preferred interim end-point until final disposition decisions on the reactors can be made.

Material Processing Hot Cell Line in Building 327 at Hanford

A new ASTD project at Hanford's Building 327 Hot Cell Facility will significantly reduce the footprint of this facility along the river corridor and likely assist in releasing some areas to the city of Richland for industrial reuse. Specifically, this project supports the accelerated deployment of a suite of innovative characterization technologies, reducing the need for decontamination, size reduction, and material handling. The goal of this project is to show that through the use of nondestructive assay (NDA) techniques and selective dry decontamination methods, "less than TRU" (i.e., < 100 nanocuries/gram) levels can be achieved on the Building 327 hot cells. If achieved, this will allow removal of the Building 327 hot cells as monolithic units and individual waste packages, which represents a significant departure from the current technical baseline, greatly minimizes secondary waste, and results in a cost savings of $10.3 million.

The ability to accelerate cleanup of the river corridor may be constrained by Hanford's available disposal capacity. Thus, Hanford is investigating the use of the massive canyon facilities as additional disposal sites. As part of the Canyon Disposition Initiative, nine technologies were deployed that helped in assessing the radiological risk within the U-Plant, which was required to determine the feasibility of using this massive facility for waste disposal. A Record of Decision is expected regarding the ultimate end state of the U-plant.

An LSDDP at the West Valley Demonstration Project Site, near Buffalo, New York, was initiated in late FY 2001. Site activities, including the vitrification of high-level waste, have resulted in highly radioactively contaminated waste in many forms, including vessels and equipment, spent ion-exchange resins, laboratory wastes, ventilation-system filters, and debris from spent fuel storage and reprocessing operations. Much of this material is stored in contaminated hot cells. The purpose of this LSDDP is to demonstrate and deploy new and innovative technologies for deactivation and decommissioning of extremely radioactive hot cells at West Valley and throughout the complex. This will require size reducing, removing, and packaging the equipment and debris to achieve the site's mission and reach its end state.

The Idaho National Engineering and Environmental Laboratory (INEEL) Fuel Storage Canals and Associated Facilities LSDDP was an extremely successful project completed at the end of FY 2001. Seventeen innovative technologies were demonstrated, of which 13 have been subsequently deployed one or more times. Resulting deployments at INEEL alone are expected to generate cost savings and mortgage reductions of $20 million. As a result of the success of this project, the NETL initiated a follow-on project with INEEL in late FY 2001. The focus of this project is to facilitate complex-wide application of the technologies proven successful in the earlier LSDDP. These deployments (11 through June 2002) target fuel pools and associated facilities, as well as material dispositioning at multiple sites, including INEEL, Savannah River, Mound, Fernald, Hanford, and Oak Ridge. This project is of great interest to the DOE Commercial Nuclear Utilities Deactivation and Decommissioning Consortium, which provides opportunities for use of improved technologies in the commercial nuclear utility market.

Two ASTD projects were recently completed that were also of particular interest to commercial nuclear utilities. These ASTD projects were the cleanout of the F-Reactor Fuel Storage Basin at Hanford and treatment of the R-Reactor Disassembly Basin water at Savannah River. The F-Reactor basin cleanout presented some complex challenges, including identification, removal, and disposal of miscellaneous irradiated/contaminated debris buried under 20 feet of sandy soil backfilled into the basin in 1970 when the facility was shut down. Using innovative technologies, Hanford was able to successfully remove and segregate the debris safely and ahead of schedule. Cost savings using the improved technologies were $4 million, representing a 5:1 return on investment.

The second project deployed two different ion-exchange approaches to remove Cs-137 and Sr-90 from 5 million gallons of basin water. The Highly Selective Nuclide Removal Systems (NURES), developed by Selion Technologies of Finland, uses ion-exchange principles that incorporate inorganic media for selective removal of targeted radionuclides. The second technology, Selective Separation Cartridge™, uses a selective membrane developed by 3M Corporation. The 3M technology is innovative in that it is made of sorbent particles enmeshed into the membrane. Both skid-mounted systems performed well, removing 98 to 99 percent of the Cs-137. Removal efficiency for Sr-90 was not as high (~ 90 percent) because of calcium interference. The 3M system was used to complete the treatment effort, saving Savannah River approximately $5 million and accelerating schedules by 5-7 years compared to the baseline approach.

The NETL is also supporting alternatives to high-risk, high-cost baselines in areas other than deactivation and decommissioning. Bio-Imaging Research, Inc., of Lincolnshire, IL, developed Waste Inspection Tomography, which characterizes the contents of a radioactive waste drum without the high costs and risks associated with opening the drum and analyzing its contents. Bio-Imaging Research is under contract with Westinghouse TRU Solutions, the M&O contractor for the WIPP, to provide mobile drum inspection before drums are shipped to the WIPP. The life-cycle cost savings for this deployment is approximately $14 million.

Characterization of Waste Drums Using Waste Inspection Tomography

DOE's Savannah River Site (SRS) stores Pu-238-contaminated TRU waste. This waste may not be shippable to WIPP in approved (TRUPACT-II) containers because of excessive generation of hydrogen gas caused by radiolysis of organic constituents in the waste matrix. Treatment of this waste to destroy the organics (eliminating the source of hydrogen) would allow the waste to meet the TRUPACT-II hydrogen concentration limit of 5 percent. The alternative is to decontaminate the organic matrix so that the Pu-238 can be concentrated in a WIPP-compliant package and the organic portion of the waste can be disposed of as low-level mixed waste. In FY 2001, the NETL awarded four contracts to private-sector companies to develop technologies that address this high-priority SRS need.

At the University of South Carolina, researchers are developing a Seismic Reflection Technology for the Detection of DNAPLs. This non-invasive technology provides a detailed picture of the subsurface, including geological stratification and detection of DNAPLs. The technology was deployed at DOE Pantex to locate DNAPLs at the Playa 3 Site. Invasive techniques, such as drilling, are precluded at this site because of the risks associated with mobilizing contaminants into the giant Ogallala Aquifer that lies beneath the site. It is hoped that seismic reflection will be able to accurately pinpoint the DNAPL sources non-invasively, so that remediation can be implemented.

Alliances with universities, such as the University of South Carolina, are essential components of the NETL's balanced portfolio for EM science and technology. Research universities offer technical assistance and applied R&D in specific areas where expertise is not readily available within the DOE complex (e.g., instrumentation, modeling, and parametric studies). Other universities supported by the NETL include Mississippi State University, Florida International University, West Virginia University Electronics Recycling Center, the Tulane/Xavier Center for Bioenvironmental Research, and a consortium of six universities constituting the Consortium for Risk Evaluation with Stakeholder Participation.

Planned Activities

As EM transitions into its new thrust area activities, the NETL will continue to work cooperatively with the Science and Technology Program to bring in the necessary expertise from private industry and universities to help solve the most urgent problems faced by EM sites. These efforts will include reviewing site baseline plans and providing technical assistance to site project managers to help determine if alternative engineering approaches may provide improvements in terms of risk reduction, cost reduction, or schedule acceleration compared to the baseline approach. The NETL will also provide the mechanism to partner with private sector companies to assist them in developing improved technologies that will result in solutions to high-risk, high-cost baselines. Finally, the NETL will continue to maintain a core technology program to develop, validate, and rapidly disseminate these improved technologies throughout the DOE complex for widespread application.

6.2 Center for Acquisition and Business Excellence: Technical and Business Services for DOE

Program Status

The Center for Acquisition and Business Excellence (CABE) is an independent Federal consulting group that provides program, project, cost, and acquisition planning, as well as management expertise. The CABE provides a critical role to its primary customer, the Office of Environmental Management, and an increasingly vital role to the entire Department of Energy in the areas of project management, business and management systems and processes, analyses, reviews, assessments, cost engineering, and value engineering.

The goals of the CABE are to:

- Continue to fulfill a key and expanded role in areas identified in the President's FY 2003 budget to Congress, namely:

  - Improve DOE's contract management by assisting in the development of improved acquisition processes by integrating project management, financial management, and DOE oversight processes.
  - Improve the identification and extent of uncertainty and risks, seeking to establish appropriate contract management mechanisms and processes, to focus upon efforts that ensure real risk reduction.
  - Improve the Department's approaches and implementation of project management principles to streamline, expedite, and raise the standard of performance.

- Continue to perform analyses (e.g., project management, cost engineering, and compliance agreements) and to emphasize and maximize the use of knowledge assets (people, databases, and reports) to increase knowledge sharing and learning across the DOE complex.

- Continue to support the DOE project management improvement initiative, in accordance with a Memorandum of Agreement with the Office of Engineering and Construction Management (OECM), in four primary areas, including project management, external independent reviews, cost engineering, and value engineering.

- Maintain preparedness to lead, or participate in, internal reviews of several major projects for DOE's Program Offices, including the Office of Engineering and Construction Management, the Office of Environmental Management, the Office of Fossil Energy, the Office of Civilian Radioactive Waste Management, and the National Nuclear Security Administration.

Program Planning and Analysis

The CABE led the scheduling discipline for the EM Office of Project Management (EM-6). FY 2001 noteworthy accomplishments included: chairing a scheduling session at the EM Project Management Workshop; presenting a series of scheduling tutorials during the biweekly EM-6 teleconferences; and conducting a schedule software-tool survey of the field program offices. This work contributes to improved project management throughout the EM program.

In FY 2001, the CABE led the development of EM's "Guidance for Environmental Cleanup and Compliance Agreements and Related Milestones." The CABE's leadership role in developing this guidance included field office and headquarters participation and review. The guidance was accepted by the Field Management Council and signed by EM-1 in January 2001.

The CABE prepares an annual analysis of functional support costs for EM, which assesses trends at each site and for EM as a whole. This has been an indicator of EM's success in cleanup activities.

The CABE led the Cost Uncertainty Analysis for EM, a critical aspect of the Inspector General's acceptance of DOE's financial statements. Because of the rigorous, thorough, and consistent implementation of the Cost Uncertainty Analysis, the IG, with the KPMG auditors, accepted the CABE's analysis without qualification.

Through a Memorandum of Agreement with the Office of Engineering and Construction Management, the CABE continues to lead the Department in developing a value engineering (VE) program as mandated by the Office of Management and Budget.

During FY 2001, the CABE began to develop Departmental VE policy, criteria, and guidelines for both in-house personnel and contractors to identify programs/projects with the most potential to yield savings from the VE techniques. The CABE has been working in conjunction with the Office of Management and Budget (OMB) to ensure that the department's evolving VE policy meets the intent of OMB Circular A-131, Value Engineering, and of Public Law 104-106, Section 4306, Value Engineering for Federal Agencies. In conjunction with VE policy development, support was also provided to OECM for ongoing DOE project management improvement initiatives by defining VE requirements and processes for inclusion in the upcoming reissue of the DOE Project Management Manual and Project Management Practices Guide.

Acquisition Planning

The CABE, as a recognized leader in innovative approaches to acquisition planning and management, was actively involved in supporting the DOE OECM, the former Contract Reform and Privatization Project Office (PC), the National Nuclear Security Administration (NNSA), and EM across the acquisition management and planning spectrum. This support included planning, awarding, and managing various programmatic initiatives, including the DOE Project Management Career Development Program, the External Independent Review program and process, and numerous other general support tasks, studies, cooperative agreements, and analyses.

The CABE played a key role in developing the proposed Acquisition Risk Management (ARM) policy and guidance and provided direct support to the Idaho High-Level Waste Vitrification ARM pilot study. The CABE has also been active in supporting the continued development of the DOE M 413.3 Program/Project Management Manual in the area of acquisition planning and management. The CABE's work in acquisition planning and management has resulted in improved DOE policies and practices relative to securing technical services and capital assets, as well as in evaluating the effectiveness of contracting strategies.

Program and Project Management

As requested by multiple DOE customers, the CABE performed more than 20 program and project reviews during the past fiscal year. These reviews ranged from Baseline Validation Reviews at another national laboratory to Independent Project Reviews (IPR) at five DOE sites**.** Results from these unbiased, independent reviews have enabled DOE HQ and site personnel to be more informed regarding the status of their programs and projects, with the CABE becoming an increasingly in-demand (Federal) service provider. The CABE continues to provide quality support by participating in and leading program and project reviews across several program areas. These reviews help to provide insights into program/project performance and maturity, aid in the development of important lessons-learned, provide value-adding recommendations consistent with DOE policy and best business practices, and support critical decisions.

In accordance with a Memorandum of Agreement, the CABE serves as the lead Federal support group to the Office of Engineering and Construction Management to establish and manage the Department's external independent review program. Since 1998, the CABE has been integral in the management of this $35 million program that seeks to ensure that over 80 DOE capital asset projects have been initiated, planned, executed, and controlled not only by Departmental guidance, but by industry's best practices as well.

In addition, the CABE continues to lead the business team for the Office of Science and Technology (OST/EM-50), which (1) successfully developed and distributed, to the entire EM-50 complex, the Cost Performance Variance Analysis Report and (2) successfully developed and conducted quarterly EM-50 quarterly business reviews. The CABE generally performed all business functions related to EM-50, including documenting costs for improved technologies to aid decision-makers in selecting technologies for use in the EM cleanup program.

Cost Engineering

The CABE continued to provide a leadership role on the Applied Cost Engineering (ACE) team. The ACE team is a joint field-HQ group encouraging continuous cost engineering performance improvement for the EM projects. The NETL provided the necessary procurement support for the ACE team. The team facilitated cost reductions at the sites by providing field project managers the knowledge and tools to evaluate contractor-submitted scope and cost estimates, and to enable scope and cost comparisons for similar projects across the EM complex and other Federal agencies.

The CABE has developed the first phase of the web-based Environmental Cost Analysis System (ECAS) for the ACE team. ECAS is used to collect, store, maintain, analyze, and report actual cost data for completed EM site cleanup projects. The ECAS fulfills the need to capture detailed cost data and understand those parameters that influence DOE EM project costs.

The CABE provides technical oversight for the development and installation of a web-based version of the Remedial Action Cost Engineering and Requirements System (RACER). During FY 2001, a new task order for including five new cost models into RACER was put in place, with an estimated completion date of June 2002. The purpose of these new models is to estimate specific Deactivation and Decommissioning (D&D) activities so that DOE can improve the accuracy and quality of its cost estimates, especially for high-risk D&D projects as noted in EM's *Top-to-Bottom Review* report. Also during FY 2001, an Interagency Agreement between the U.S. National Institute of Standards and Technology (NIST) and the NETL was formed to develop a standardized Guide to Computing and Reporting the Life-Cycle Costs of Environmental Management Projects as well as an accompanying software implementation guide.

During FY 2001, the CABE provided input to OECM and the DOE field offices in the development of the DOE Program and Project Management Manual. The Cost Engineering input has solidified the ways that cost and schedule estimates are used by Program and Project Managers in terms of budgeting, contracting, and the day-to-day project management purposes, such as value engineering and earned value reporting. As part of the cost-estimation improvement effort, OECM requested that the CABE manage the development of the escalation rates to be identified in DOE's budget formulation guidance.

The CABE also served as lead for DOE in the area of cost engineering (CE). The DOE Cost Engineering Group (CEG) was established and is co-led by the NETL and OECM. The objectives of the CEG are to address complex-wide cost engineering issues, such as consistency, standardization, cost and schedule estimate quality, and reliability. The DOE partnership agreement with the Association for the Advancement of Cost Engineers (AACE) was renewed and will aid DOE in exchanging lessons learned with industry and academia.

Planned Activities

The CABE will continue to provide high-quality products and services consistent with its mission to the Office of Environmental Management, the Office of Engineering and Construction Management, and the National Nuclear Security Administration. Additionally, the CABE anticipates expanding its business base to support other DOE customers that desire support from this unique Federal capability.

6.3 Commercial Nuclear Utility Decommissioning

There are 442 commercial nuclear power plants worldwide, 109 of which are located in the United States. Because of deregulation, electric utilities must decide whether to extend operating licenses for nuclear power plants or to decommission them when they reach the end of their current licenses. Economic, environmental, and stakeholder factors must be considered in making these decisions.

Eleven nuclear power plants are currently being decommissioned or will soon begin decommissioning. The current estimated cost to decommission a nuclear power plant is $500 million to $550 million, which includes the cost of temporary storage of spent fuel until the DOE geological repository opens (projected in the 2010 to 2016 time period). Therefore, the ultimate cost to decommission 109 nuclear power plants in the United States is estimated at $54 billion to $60 billion.

Program Status

To address the significant hurdles faced by the ultimate need to close commercial nuclear power plants, a DOE/Utility Decontamination and Decommissioning Consortium was formed in December 1997. To create the consortium, DOE signed a Memorandum of Understanding with EPRI and several nuclear utilities and agreed to jointly develop, demonstrate, and deploy improved decontamination and decommissioning (D&D) technologies in ongoing decommissioning projects within DOE and the nuclear utility industry. This agreement established the initial membership of the DOE/Utility Decontamination and Decommissioning Consortium and a charter was established in early 1998. The consortium facilitates the exchange of best business practices and lessons learned, and plans and executes a leveraged technology program designed to meet the technical needs of both DOE and the commercial nuclear utilities. The consortium has expanded during the past four years to include a total of nine nuclear utilities.

Benefits of the DOE/Utility Decontamination and Decommissioning Consortium include:

- Cost sharing reduces the cost to implement new and improved deactivation and decommissioning technologies within DOE and the nuclear utilities.
- Collaboration reduces decommissioning costs for the ratepayers of electric utilities that own nuclear power plants and the taxpayers that fund DOE's decommissioning program.
- Deployment of improved deactivation and decommissioning technologies improves safety, accelerates schedules, and reduces worker radiation exposure.
- Collaboration leads to a mechanism to share information on improved D&D technologies.

DOE and EPRI are jointly sponsoring workshops held at various commercial nuclear power plants around the country. Each workshop has focused on a specific topical area relevant to decommissioning of radioactively contaminated facilities. A total of 11 workshops have been held, enabling DOE and the utilities to openly share technical information.

Three technologies were successfully demonstrated at two different commercial utility sites. Concrete shaving technology, developed by Marcrist Industries, Limited, and licensed by Bluegrass Concrete Cutting, Inc., and an online decontamination unit developed by the Hemispheric Center for Environmental Technology at Florida International University were demonstrated at the Rancho Seco nuclear power plant. A mobile pipe decontamination and characterization system developed by the Hemispheric Center for Environmental Technology was demonstrated at the Big Rock Point nuclear power plant.

Planned Activities

The NETL will continue to seek opportunities to collaborate with EPRI and the nuclear utilities as part of the DOE/Utility Decontamination and Decommissioning Consortium. Future collaboration will likely involve additional topical workshops to share decommissioning experiences and joint development, demonstration, and deployment of improved decontamination and decommissioning technologies that benefit both nuclear power plants and DOE decommissioning projects. In addition, the NETL, EPRI, and nuclear utilities will continue to organize joint sessions in major international conferences such as Spectrum, as well as periodic and annual meetings of the American Nuclear Society.

7 Energy Policy Analysis

Energy accounts for 7 percent of gross domestic product (GDP), or approximately $2,000 per year for each person in the United States. Indirect effects of energy use impact virtually every aspect of the economy and environment, including prices, employment, land use, and air and greenhouse gas emissions. Additionally, there is a demonstrated correlation on an international level between energy use and per capita GDP, with per capita GDP rising with increased energy use.

Fossil fuels provide 85 percent of the energy used in the United States. The Department has forecast that this percentage will rise to 87 percent by 2020. There are multiple and conflicting considerations in determining the future application of these resources to meet the rising demand for energy in the United States and the world. Among these are questions of availability, affordability, and acceptability in a sometimes-conflicting international economic and political climate.

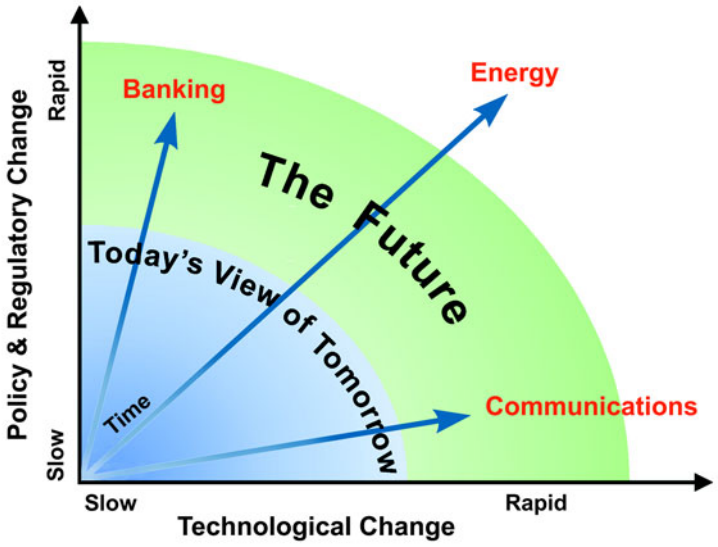
Questions of availability, affordability, and acceptability of energy resources require sound policy development. The myriad of lower-level questions contain many possible options for action. Policy makers require technical information in a useful format to develop sound policy. It is in this context that the NETL provides analyses and knowledge products to support development of these policies.

This responsibility has been implemented by providing:

- Programmatic leadership.
- Technical, analytical, and planning expertise.
- Tools and solutions to both the domestic and international energy communities.
- Assessments of the technical, environmental, and cost performance of technologies.

These studies include risk-benefit analyses, policy support and analysis activities, analyses of trends within the energy sector, regulatory impact studies, environmental assessments, and detailed engineering reviews in support of the NETL RD&D projects.

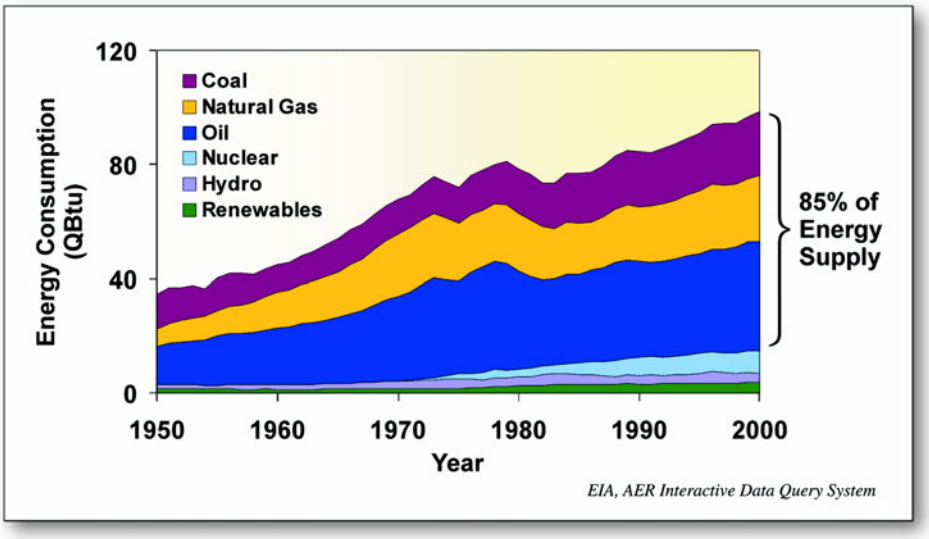
Our objective is to establish the NETL as a reliable and trusted source of information about the performance and cost of fossil fuel-based technologies and the comparison of these to competing technologies under a range of future scenarios.



Changes in every industry driven by both technological and policy/regulatory change

7.1 Fossil Fuel Issues

America's economic engine is fueled primarily by fossil fuels. Coal, oil, and natural gas supply 85 percent of the Nation's total energy, 70 percent of its electricity, and nearly 100 percent of its transportation fuels.



By 2020, because of the projected growth in natural gas consumption, DOE forecasts that fossil fuels will be supplying 87 percent of the Nation's energy. The abundance and affordability of coal and natural gas are the main reasons why U.S. consumers benefit from some of the lowest electricity rates in the world. Our economy is strong largely because of these fuels. Our environment is becoming cleaner because we have invested in clean coal and other low-polluting technologies.

Today, the future availability, cost, and reliability of our traditional fuels are being questioned. The terrorist attacks in the United States and the resulting threats to energy supply, significant dependence on oil and gas imports, aging infrastructure, power transmission bottlenecks in the Northwest and New England, gas pipeline constraints in the Northeast, and reduced reserve capacity all raise concerns over whether the United States can continue to rely on the fuels that historically have powered its economic growth.

As an example, typical central generating stations for electricity production have long operating lifetimes. Utility deregulation in the United States is underway, but has been implemented only in some States and has produced considerable uncertainty in the utility sector. Experiences with the process to date have raised serious questions as to how the emerging market will respond to both near-term needs for power and choices about the next generation of technologies to be adopted.

A comprehensive national energy policy has been developed for the United States. This plan recommended a multi-pollutant strategy to require power plants to reduce emissions of sulfur dioxide, nitrogen oxides, and mercury. The proposed Clear Skies Initiative responds to this recommendation. The initiative includes phasing in reductions over a reasonable period of time, providing regulatory certainty, and offering market-based incentives to help industry meet established targets. Technologies under development through the NETL should contribute to the success of this initiative. Studies are being initiated to explore the issues inherent in the deployment strategy to ensure success.

Program Status

The NETL has been involved in modeling technology performance and associated costs for some time. We have also involved ourselves through cosponsorship and participation in meetings of modelers to identify issues in accurately reflecting technology improvements and to gauge the response of society to their deployment.

We work with the Office of Policy, EE–Office of Building Technologies, EPA, and the International Energy Agency to explore means to improve these types of models. We work with Carnegie Mellon University to enhance the capabilities of the Integrated Environmental Control Model as an important tool to assess the full cost of multi-pollutant control, and to develop probabilistic estimates of the likely distribution of true costs for technologies.

Existing models are often criticized for the uneven representation of the technologies they incorporate. A key element of our activities is to develop input data sets that accurately reflect current cost and performance of technologies exiting the developmental pipeline and to understand and represent the potential of these technologies to improve over time, a form of technological learning.

In addition, the NETL has available a large resource of information on fossil-fuel technologies throughout their development cycle. We are well positioned to perform analyses based on projections of improvements in the technology, trends within the industries that might use them, and larger shifts in society that might favor one technology over another.

As a result of these capabilities, knowledge management tools are being developed and made widely available to address issues regarding lack of high-quality, representative results and the data needed to run energy system models such as MARKAL. Currently, an effort is underway to capture and share the knowledge base that the NETL has developed on the costs to control mercury emissions from coal-fired power plants.

The NETL has provided critical databases to EIA for its analysis of mercury issues, visiting EIA offices to educate and disseminate a current understanding of the technical issues impacting mercury emissions and their control. We are also helping EIA to incorporate NETL-developed databases into the National Energy Modeling System (NEMS). In addition, EPA requested our assistance on its peer-reviewed Mercury Control Technology Report. This report, which incorporates an NETL-written critical review on mercury measurement and control, will aid in developing accurate mercury-control costs based mostly on DOE/NETL-derived data.

Planned Activities

The existing fleet of coal-fired power plants comprises diverse designs spanning more than half a century. These plants tend to be large and infrequently idle. The immensity of the fuel requirements and the associated pollution raise the visibility of these plants as a target for improvement. Up to this point, regulatory standards for pollutants from these plants have focused principally on one pollutant at a time. These standards typically evoke control technologies that are incremental in nature. Since the life of a power plant far exceeds the life of a regulatory standard, there is an opportunity to consider the impact of improvement across the existing fleet throughout the life cycle of a power plant and the electric power-generation system.

Multi-pollutant control options are modeled over a timeframe that does not adequately consider learning-curve estimates for emerging technologies. Results from existing models leave unanswered the question of the potential to combine benefits for policy and regulatory processes over a reasonable timeframe to allow for new approaches to pollutant control. In addition, complex forecasts of power-generation needs often oversimplify factors of availability, performance, and cost for the wide range of technology options to be considered. Uncertainties in critical areas of technology development and deployment are often reduced to sensitivity cases that do not fully integrate technological and economic uncertainty.

A new approach and product are desired. Important results from such an analytical model would include:

- Cost of implementation for various policy options.
- Impacts on affected facilities and system capacity through early retirement options.
- Assessment of New Source Review issues for permitting power generation.
- Options analysis for any policy or regulatory negotiation position.

The value of analyzing risks associated with (1) the highly dynamic nature of our energy supply system and (2) the convergence between energy resource sectors (e.g., the natural gas industry is becoming closely aligned with the electricity industry) is obvious. In order to obviate the need for crisis management, a longer term, comprehensive study aimed at understanding energy supply issues and the convergence amongst fuel sources, production and use technologies, and the transmission and storage infrastructure in the United States is underway at the NETL.

The topic of infrastructure reliability and the risks associated with this issue have drawn a large amount of attention. EIA regularly makes projections regarding availability and cost of energy resources. Modeling studies have explored a number of alternative scenarios for future energy demand and the slate of technologies needed to satisfy this demand. Some models perform analyses based on annual averages; other models focus on sectors in the economy and analyze seasonal variations. However, no model can currently address the issues tied to expected trends such as energy system convergence between electricity and fuel sources. That deficiency, coupled with a need to analyze emergency response strategies, is crucial to assessing preparedness and identifying research needs in infrastructure reliability.

The NETL makes routine use of models, such as the Integrated Environmental Control Model, the Total Oil Recovery Information System, and the Gas Systems Analysis Model, as well as modeling tools such as ASPEN PLUS and the ICARUS Process Evaluator, to examine technological and microeconomic issues. Collectively, these models represent a powerful tool for exploring the convergence occurring within the energy sector.

A study is beginning that will focus on the impact of decisionmaking, short-term fluctuations in energy markets, and the intersection of technology performance and reliability issues to explore disruptions in energy supply. Technology choices tend to create new opportunities both to address emergency preparedness needs and to impose new limits for addressing unexpected consequences.

Planned activities will:

- Develop tools to estimate the option value of a technology choice.
- Develop approaches to project performance goals and factors required for market acceptance for advanced power-generation technologies under development.
- Establish partnerships with key organizations to support modeling and analysis activities outside current NETL efforts.

7.2 Climate Change Support

There is continuing international pressure to reduce CO_2 emissions

Irrefutable evidence that global climate is changing has raised concerns over the impact of man as a causal agent in these changes. Although it is not clear what percentage of the detected changes in climate is attributable to anthropogenic sources, the leadtime required to change the emission of gases contributing to this greenhouse effect and for the natural systems to reestablish a new equilibrium is long.

Fossil fuels supply approximately 85 percent of the energy needs both in the United States and in the world. Sources of CO_2, the primary gas of concern in terms of its potential to force climate change, are distributed nearly equally across the transportation, industrial, and residential and commercial sectors of the economy. Moreover, generating the electricity used by the residential, commercial, and industrial sectors produces a third of total CO_2 emissions. Other gases and fine particulate emissions that may contribute to the atmospheric chemistry that drives climate forcing are produced by human activity, including the burning of fossil fuels.

Developed nations are the largest sources of these emissions. However, emissions in developing countries are increasing at such a pace that, within the first third of this century, emissions in developing countries will surpass those in the developed world. The pace of electrification in developing countries—representing 80 percent of the population of the world—is rapid and is being driven by the use of indigenous resources, primarily coal and natural gas. Current international agreements exempt developing nations from compliance requirements. Controlling greenhouse gas emissions, with the eventual goal of stabilizing atmospheric concentrations at some level, will require action within both the developed world, including the United States, and in developing nations.

It is important that we carefully consider the impact—both for the economy and for the technology strategies designed to meet the energy needs of the Nation—of possible policies to mitigate greenhouse gas emissions or to adapt to changing climatic conditions. We must understand various scenarios for the future of energy supply and marketing as a key aspect of planning for our R&D programs. This issue is also closely tied to questions of how best to meet emerging environmental regulations for other pollutants, such as nitrogen oxides, mercury, and fine particulates.

The Administration has said: *"… we will continue to fully examine global climate change issues—including the science, technologies, market-based systems, and innovative options for addressing concentrations of greenhouse gases in the atmosphere. I am very optimistic that, with the proper focus and working with our friends and allies, we will be able to develop technologies, market incentives, and other creative ways to address global climate change."*

George W. Bush
President of the United States

Program Status

A primary component of the work to date has been to establish roles for the NETL within the community working on climate change issues. We have done this in several notable ways, as detailed below.

Energy and environmental decisionmaking are inextricably linked. Deployment of fossil fuel-based technologies now occurs in a national and global environment where those purchasing technologies may consider provisions to manage carbon emissions. We have responded by exploring the issues underlying policy options, such as carbon taxes and emissions trading, to gauge the impact of these measures on technologies that we are supporting. These studies focus on identifying issues emerging in negotiations under the United Nations Framework Convention and continue in an effort to develop appropriate international trading mechanisms and markets.

The purpose of market-based incentives is to increase flexibility and reduce the costs associated with reducing emissions. An effort is directed toward developing protocols that estimate greenhouse gas emission reductions resulting from potential projects undertaken in the power sector. It deals specifically with the difficult and complex problem of developing emission baselines for projects. We are attempting to assess baseline estimation procedures further by applying a technology matrix to case studies to minimize transaction costs and accurately estimate real reductions in greenhouse gas emissions.

Numerous studies have been conducted that examine policy options and their impact on the United States. NEMS has been used to explore various technology options. Other modeling approaches, including the MARKAL family of models, are routinely used to explore policy issues related to mitigating climate change, defining innovative approaches to environmental regulation or alternative compliance strategies, and to exploring the impact of the human dimensions of the problem. The NETL has been developing expertise in the use of NEMS through interactions with EIA and the DOE Policy Office on two studies: a multi-pollutant control study completed in early 2001, and a study on low-sulfur diesel fuel.

We have begun to evaluate the use of models, such as NEMS and MARKAL-MACRO, alongside those models routinely used at the Laboratory to evaluate technologies and explore impacts of new energy, environmental, and economic policies. We are expanding our use of these models to better gauge the interaction of technology developments with potential changes in demand, economics, and societal attitudes.

We have worked with EPA to model innovative approaches to simultaneously control CO_2 and other targeted pollutants ("co-control"). Initial studies have focused on developing a detailed technological representation of a portion of the generating capacity in a region heavily dependent on coal for both power generation and revenue to explore a scenario that phases in a series of control requirements. This study is intended to evaluate the potential of a technology-rich simulation in exploring costs, benefits, and alternative compliance strategies as compared to more traditional risk-driven, economics-based studies.

We are also working with EE's Clean Cities International program to disseminate information about increasing the use of alternative fuel vehicles and the impact on both particulate pollution and greenhouse gas emissions.

In other notable activities conducted under the current program, the NETL:

- Examined the reduction in climate change that could be attributed to reduced NO_x emissions resulting from compliance with State Implementation Plans.

- Established relationships with EPA's Office of International Activities and Office of Air and Radiation (Office of Atmospheric Programs) on transboundary pollution and climate change mitigation.

- Jointly sponsored a workshop on advanced concepts for carbon sequestration with Los Alamos National Laboratory and Texas Utilities.

- Developed a formal agreement with the National Renewable Energy Laboratory to collaborate on energy modeling.

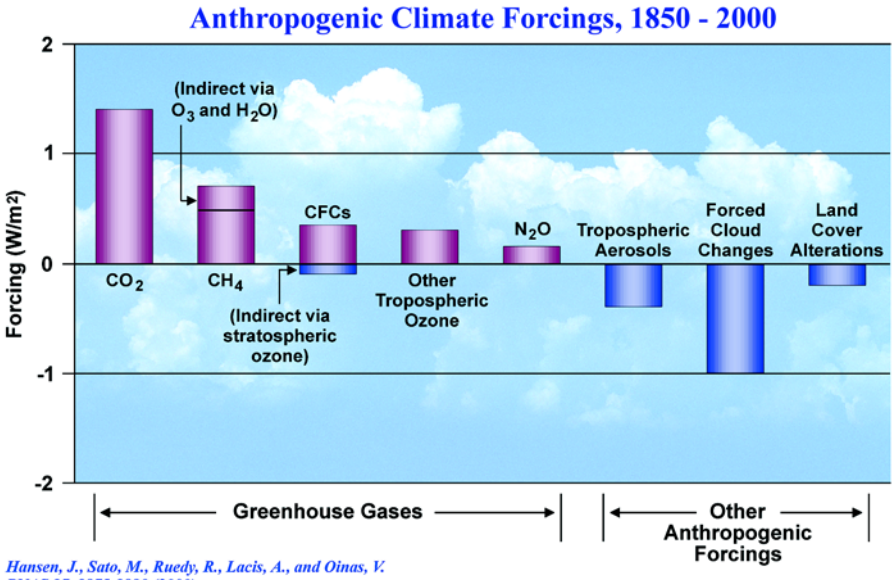
Planned Activities

Recent articles by Hansen, Wuebbles, and others have suggested a new avenue toward significant progress in managing the risks associated with anthropogenic contributions to global climate change. These authors offered the idea that control strategies that address traditional criteria pollutants, such as SO_2, NO_x, and aerosols, along with reduction of CO_2, could be effective and might engage developing nations to take steps that address climate change. In general, the approach proposed control of criteria pollutants, including mercury, along with measures to reduce greenhouse gases such as carbon dioxide and methane. This approach assumed that deployment of technologies for advanced power generation, control of methane emissions at natural and man-made sources, and other least-regrets options could have a significant impact.

To judge the efficacy of such an approach, technology-deployment strategies, their concomitant impacts on emissions and human health, and changes in the characteristics of the atmosphere must be examined together. In this case, changes in the properties of the atmosphere important to global climate change could be viewed as the metric for the deployment strategies. Should the approach demonstrate new insight into the issues surrounding development of workable mitigation and adaptation strategies, a more complete analysis, including economic analysis and policy options, could be performed.

Significant gaps exist in our knowledge of the atmosphere. For instance, many questions remain unanswered about the impact of aerosols and different types of black carbon on global warming. A key outcome of the early phases of this effort will be to set research priorities for characterizing emissions and their sources based on their potential impact on climate.

The NETL is initiating work to explore the impact of reductions in criteria pollutants proposed under environmental regulations coming into force and new congressional and Administration proposals, such as a multi-pollutant control strategy. In addition, work is underway to explore the potential offered by sequestration by developing supply curves (i.e., estimating the potential capacity available to store CO_2 at a given total cost for capture, separation, transport, and storage). These studies will also focus on the impact of different energy-production technologies on these costs.

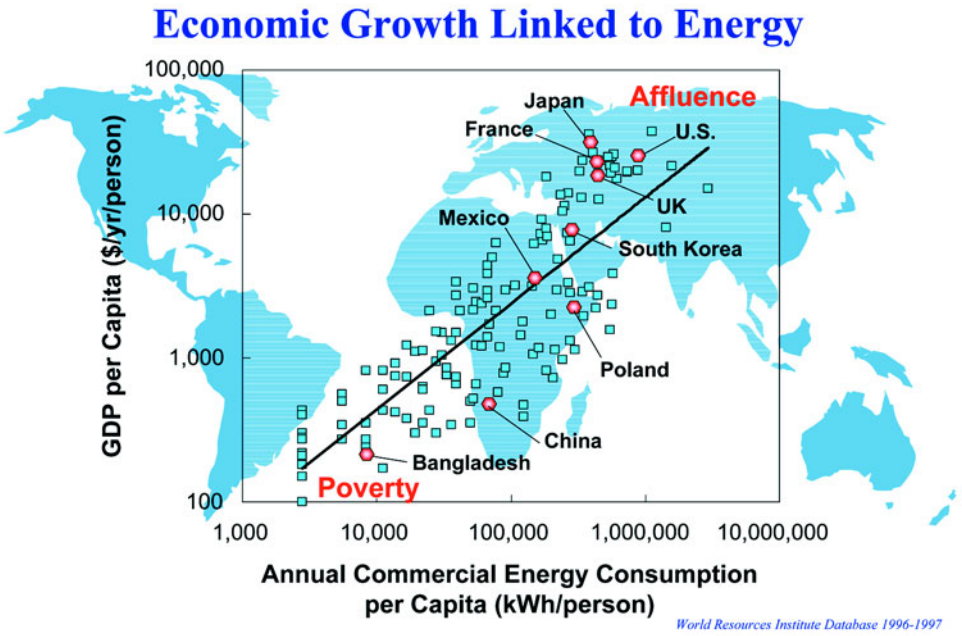


Hansen, J., Sato, M., Ruedy, R., Lacis, A., and Oinas, V. PNAS 97, 9875-9880 (2000)

7.3 International Projects: A Critical Element in Addressing Climate Change

The NETL has structured its International program in response to the following strategic drivers to meet the needs of the Administration and the U.S. private sector:

- ***Energy Security***—Promote the efficient use of world energy resources and diversify U.S. energy supplies.
- ***Trade Promotion***—Expand existing and open new markets for U.S. energy and environmental technologies, products, and services.
- ***Science and Technology***—Reduce the cost and enhance technical accomplishments of RD&D programs through cost-shared, collaborative, international relationships.
- ***Environmental Security***—Promote technologies and solutions that will improve the global environment, including greenhouse gas mitigation.



Technologies, products, and services in the energy and environmental sectors of the U.S. industrial base constitute a significant portion of our Nation's exports. The global markets for these sectors of the economy are predicted to be in the range of $42 trillion[1] and $600 billion,[2] respectively, by the year 2010. The U.S. private sector has strong global market position in these two areas, but faces significant competition from those countries that are active in these fields and seeking commercialization of their technologies. For advanced power-generation technologies, Japan and Germany are particularly formidable competitors. A number of other countries, including Japan, Canada, and Norway, have conducted greenhouse gas (particularly CO_2) control and sequestration-technology demonstrations. These countries will continue to be our private sector's strongest competitors should these technologies prove technically and economically viable or politically necessary.

The importance of CO_2 emissions as an international environmental issue has grown substantially since 1992 because of increasing concern over rising atmospheric concentrations of greenhouse gases and their possible adverse effects on the global climate system. World energy use has emerged at the center of this issue.

Program Status

DOE and FE have the technical and administrative capabilities, expertise, and history of conceptualizing, designing, conducting, implementing, and managing research, development, and demonstration programs and projects, both domestically and internationally. The NETL has a long history of working with the international community on a broad range of fossil energy topics and their related policy issues.

Historically, the NETL has been responsible for managing U.S. Agency for International Development (USAID) projects in India, Poland, and Ukraine; Trade and Development Agency-funded Clean Coal Technology Reverse Trade Missions from Brazil and Sri Lanka; as well as State Department Foreign Service Officers training courses on the coal and power industry. Additionally, the NETL has handled numerous requests from the U.S. Department of Commerce to assist on a broad range of technical energy and environmental export issues and events.

The current global energy situation places the NETL in an inherently strong position to leverage its energy and environmental RD&D portfolio to:

- Deliver a return on the U.S. taxpayers' investment in FE energy-related RD&D.
- Benefit the U.S. private sector through the export of energy and environmental technologies, products, and services.
- Provide proven technology and policy options to help stabilize and then reduce future world carbon emissions without compromising sustainable development goals.

Planned Activities

The NETL International program seeks to balance the technology and policy interests and mandates of the Administration with the efforts of the U.S. private sector to market and export its energy and environmental products, technologies, and services. Specific goals of the program are to deploy advanced power-generation and greenhouse-gas-emissions-control and sequestration technologies in key foreign countries (i.e., Mexico, Brazil, Peru, Guatemala, Argentina, Korea, China, Indonesia, Philippines, Japan, Thailand, Czech Republic, Poland, Russia, Ukraine, and South Africa). These goals can be categorized in two major areas:

- Promote appropriate U.S. greenhouse gas-oriented technologies in key foreign markets to increase export opportunities for U.S. private industry.
- Serve as a reliable information resource on the NETL greenhouse gas-oriented technologies to government and private sector stakeholders.

> *"… we recognize our international responsibilities. So in addition to acting here at home, the United States will actively help developing nations grow along a more efficient, more environmentally responsible path."*
>
> **President George W. Bush in announcing the Clear Skies and Global Climate Change Initiatives.**

NETL International Activities

Country	Activity
Bilateral Activities	
Argentina	Exchange information on fuel cell technology and promote fuel cell demonstration projects.
Brazil	Exchange information on fuel cell technology. Develop cooperative agreement on fuel cell R&D between LACTEC and NETL OST and initiate joint project(s).
Canada	Support Fossil Energy Implementing Arrangement with Natural Resources Canada on advanced power generation, environmental control technologies, and transportation fuels and chemicals. Assist with developing annex on Weyburn CO_2 Sequestration Project Annex to permit NETL funding of project. Explore cooperation with National Research Council. Support Fuel Cell Implementing Arrangement. Support CANMET Consortium on Conversion of Natural Gas.
China	Initiate projects under new United States-China Fossil Energy Protocol, including conduct of NO_x/SO_2 Control Workshop under Annex I (Advanced Power Technologies) and joint CO_2 capture and sequestration R&D project and training course on U.S. flue gas desulfurization technologies and practices in China under Annex IV (Energy and Environmental Control Technologies). Assist with planning and implementation of United States-China Oil and Gas Forum.
India	Support reestablishment of United States-India bilateral fossil energy agreement. Support conduct of India-United States Coal Advisory to promote U.S. technologies.
Indonesia	Participate in Coal Tech 2002–International Conference & Exhibition on Mine Mouth Power Plants.
Italy	Renew Fossil Energy cooperative agreement and identify possible activities for cooperation related to low-carbon technologies (fuel cells, hydrogen, CO_2 sequestration, etc.).
Japan	Renew Coal Research and Fuel Cell Implementing Agreements and hold Joint Technical Meeting on Coal Research in the United States.
Korea	Identify cooperative activities to revitalize agreement.
Mexico	Participate in U.S.-Mexico Lead Coordinators Meeting. Revise existing Fossil Energy agreement into two new agreements on oil & gas and electricity, and identify possible joint activities.
Venezuela	Exchange oil-related information under agreement with Ministry of Energy and Mines. Expand agreement to include natural gas-related technologies.
Interagency Activities	
USAID/Guatemala	Continue to support project-development activities related to previously completed USAID-supported feasibility study on landfill gas-based power generation.
USAID/India	Continue to provide technical assistance to USAID/India in implementing Climate Change Supplement of the Greenhouse Gas Pollution Prevention Project.
USAID/Egypt	Complete technical assistance on design of a fuel cell testing facility for Egyptian Electricity Holding Company. Explore funding opportunity for follow-on work, including erection of fuel cell test facility and/or demonstration project.
DOS/Egypt	Complete technical assistance for fuel cell market study to Cairo University under U.S.-Egypt S&T Project.
USEPA/TCAPP	Support CCT and Industrial Boiler Projects with funding from U.S. EPA under Technology Cooperation Agreement Pilot Project (TCAPP), including conduct of PFBC workshop in the United States.
Multilateral Activities	
APEC Expert Group on Clean Fossil Energy	Lead Expert Group activities, including conduct of Joint Coal Technology and Coal Flow Seminar and Trade Investment and Liberalization and Facilitation Workshop. Complete Alternative Transportation Fuels (Phase III) and CO_2 Reduction Options (Phase II) Studies.
Hemispheric Energy Initiative	Participate in activities under Working Group 2: Clean Energy Options, and support reorganization of all Working Groups under common themes.
International Energy Agency	Coal Research: Award Fossil Energy grant and review draft reports. Greenhouse Gas Program: Exchange information on mitigation technologies and support collaborative R&D on CO_2-reduction technologies. Coal Combustion Sciences: Exchange information on basic coal-combustion science R&D.
Canada/Mexico	Explore trilateral R&D cooperation.
Latin America	Conduct Latin America Fuel Cell Workshop.

If fossil fuel use is to continue to be an option for the United States and the rest of the world, the NETL must pursue a proactive, multi-pronged approach to enhance the development and international deployment of its portfolio of advanced power-generation and greenhouse-gas-emissions-control and sequestration technologies.

In laying the groundwork for such an approach, we will utilize a variety of techniques. The NETL will continue to conduct studies of global markets for U.S. technologies and will disseminate the results to U.S. firms. We will continue our efforts in identifying and developing export and international business opportunities for advanced power-generation technologies in partnership with the U.S. private sector, and State and local economic-development and export-promotion organizations. We will conduct and participate in discussions, workshops, symposia, roundtables, and conferences with foreign partners and U.S. firms to promote U.S. technologies.

Our overall objective in utilizing these techniques is to leverage NETL resources with other government resources to overcome commercial, regulatory, and political barriers to U.S. trade and investment in the energy and environmental sectors of foreign countries. Additionally, we intend to work closely with the financing community and donor organizations to identify adequate financing for demonstration and deployment of U.S. technologies in foreign countries.

"We must look beyond our borders and restore America's credibility with overseas suppliers. In addition, we must build strong relationships with energy-producing nations in our own hemisphere, improving the outlook for trade, investment, and reliable supplies.

We should not, however, look at energy security in isolation from the rest of the world. In a global energy marketplace, U.S. energy and economic security are directly linked not only to our domestic and international energy supplies, but to those of our trading partners as well."

National Energy Policy
May 2001

As a natural outgrowth of these activities, we will educate foreign governments and firms on the technical and economic benefits of appropriate U.S. technologies in response to their requests or identified needs. We accomplish this by supporting DOE participation in international, non-governmental organizations, such as the International Energy Agency, the Asia Pacific Economic Cooperation forum, and serving as a resource to others, such as the United Nations Industrial Development Organization and the World Bank—critical political and business allies that deploy our technologies. In so doing we support development and implementation of policies that will enhance the competitiveness of U.S. energy and environment industries in foreign markets against the backdrop of worldwide commitments to stabilize greenhouse gas emissions.

We also track other countries' greenhouse gas activities, including development and deployment of advanced power-generation and greenhouse-gas-control and sequestration technologies. We strive to develop innovative, cost-shared, collaborative relationships (e.g., consortia and joint ventures) between U.S. and foreign governments, private-sector, and academic entities. These relationships allow us to conduct mutually beneficial RD&D activities and develop and implement greenhouse gas-related projects for DOE and other government agencies. Some examples of planned international activities follow.

We will provide technical assistance to the Egyptian Electricity Holding Company that could culminate in a laboratory-scale demonstration of fuel cell technology in a project supported by USAID. The NETL will jointly conduct a study with Cairo University to determine the feasibility of using fuel cells for distributed electric power generation in Egypt. This study is funded by the Department of State through the U.S.-Egypt Science & Technology Fund.

India fuels most of its power plants with low-grade domestic coal, and many of its facilities are aging and inefficient. We will continue a project, funded by USAID/India in their ongoing Greenhouse Gas Pollution Prevention Project, designed to reduce greenhouse gas emissions per unit of electricity generated in Indian power plants. Led by the NETL, more than a dozen teams have provided technical assistance to India's power stations and training to power plant engineers. The NETL also helped National Thermal Power Corporation, the sixth largest utility in the world, establish a Centre for Power Efficiency and Environmental Protection. This center is a national resource for training and technology demonstration to help improve power plant efficiency and environmental performance in India.

In the second phase of this project, the Climate Change Supplement, the NETL will assist in efforts to build a local capability to sustain greenhouse gas reductions in existing power stations. The NETL also will introduce more efficient and less-polluting technologies for new power plants, and for improving the utilization of existing assets. A detailed engineering feasibility study will be initiated to evaluate integrated gasification combined-cycle (IGCC) power-generation technology for India.

India's National Thermal Power Corporation's Singruali Power Station (2000 MWe)

[1] N. Nakicenovic, A. Grubler, and A. MacDonald, eds., Global Energy Perspectives, Cambridge, UK, Cambridge University Press, 1998.

[2] U.S. Department of Commerce, International Trade Administration Web site.

8 Laboratory Management

8.1 Management Approach

The NETL's research, development, and demonstration (RD&D) mission is accomplished through an integrated management concept. The NETL has proved its ability to make optimum use of the flexibility and mobility offered through partnering with industry, national laboratories, and others. Balanced by highly capable in-house research-and-development resources, the Lab helps to create commercially viable solutions to energy and environmental problems.

Approximately three-quarters of the NETL's annual budget for RD&D is expended on government-sponsored RD&D projects with industry and other public-private sector RD&D partnerships. Of this, more than 95 percent is awarded to private sector research groups (defined here to include academic institutions and not-for-profit organizations) as a result of competitive solicitations.

This emphasis on collaborating with the private sector has been and will continue to be an essential part of the NETL's mission management philosophy. Deployment of NETL-developed advanced technologies must be accomplished through the private sector. Therefore, early private sector intellectual and cost-sharing involvement in the RD&D process provides for accelerated deployment of new technologies. Private sector involvement also brings about a better understanding of end-user needs, and an intrinsic technology-transfer mechanism. Overall, by means of these public- and private-sector RD&D partnerships, the NETL projects that the cost, reliability, and environmental benefits offered by new technologies will mature and gain more rapid acceptance in the marketplace, thus providing optimum benefit to the public.

This section describes the management approaches used at the NETL. The NETL organizational structure (see figure 1 in chapter 9) is built from five different types of performing organizations working as a matrix. Within this structure the Product Management Offices provide the program oversight that supports the Lab's mission. The four remaining performing organizations are responsible for implementing the day-to-day activities that lead to accomplishing the NETL's mission. The basic functions of the performing organizations are:

- Product Management Offices are responsible to work with DOE Headquarters program office sponsors and other external stakeholders to conduct high-level technology development and program planning and integration.
- The Office of Project Management is responsible for the technical aspects of all procurements and for managing all external projects. This Office provides the primary implementation support to Product Managers.
- The Office of Science and Technology performs onsite research and technology development in areas where the NETL has unique expertise. This organization also provides technical experts to participate on product teams.
- The Office of Systems and Policy Support assists in the development of the policy context for product lines, and carries out studies to guide program development and provide input to policy formulation.
- The Office of Business and Logistics provides acquisition and assistance, financial management, and other administrative support for all of the NETL's activities.

Product Management

The NETL has four Offices that conduct Product Management functions:

- Strategic Center for Natural Gas.
- Office of Coal and Environmental Systems.
- National Petroleum Technology Office.
- Environmental Technology and Business Excellence (located within the Office of Project Management).

The primary function of the Product Management organizations is to work with DOE Headquarters program office sponsors and other external stakeholders to conduct high-level technology development and deployment planning.

The Product Management Offices are staffed with a cadre of Product Managers, each assigned with a specific product or technology area. For their respective product areas, each manager is responsible to maintain relations with program sponsors and other external stakeholders to:

- Determine technology-development requirements.
- Develop teaming arrangements to implement projects where appropriate.
- Define out-year budget requirements.
- Obtain feedback on the NETL's performance.

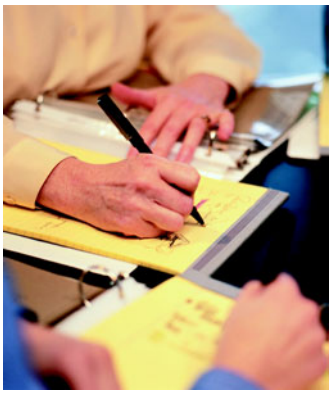
Each Product Manager leads a crosscutting team responsible for coordinating all internal NETL activities related to the product. Membership on a typical product team includes representatives from the NETL's Project Management, Science and Technology, Policy Support, and Acquisition organizations. A representative from the responsible program office at Fossil Energy Headquarters also serves on each team. Product teams:

- Determine the types of research and systems-analysis activities required to meet the expectations of external stakeholders.
- Plan high-level activities for the product including goals, metrics, funding, and key milestones.
- Prepare an annual Product Plan that is consistent with DOE's Strategic Plan.
- Provide a network across the NETL functional divisions to facilitate communication and resolve conflicts.

Separating the NETL's Product Management activities from day-to-day product-implementation activities has led to a stronger and more interactive planning function.

Through product team participation, onsite researchers frequently participate in reviews of contracted research. This practice brings additional scientific expertise to the project review process. At the same time, onsite research personnel obtain insights from conducting hands-on research and in the review and evaluation of findings from the contracted activity. This broad exposure of NETL personnel also helps to develop the next generation of Product Managers.

Project Management



A proven NETL strength is the ability to manage external RD&D. The NETL uses this to draw on the experience and expertise of industrial and academic partners to respond to the energy needs of the Nation. Working with industry also provides the added benefit of bringing technologies to market with the full understanding of the regulatory and statutory requirements necessary to maximize the potential benefit to the public. The Office of Project Management consists of eight technology-focused Divisions that are aligned with a specific product focus. Fifteen to 20 Project Managers staff each Division, each overseeing an average of 10 projects. The primary duties of the Project Managers are to function as the technology liaison and strategist for the acquisition and assistance process. The Project Manager generates the technical specifications for solicitations and makes all technical decisions in the planning, solicitation, evaluation, award, evaluation, management, and closeout phases of all awards. The matrix organizational structure facilitates dialogue among key players in the procurement process. A strategic planning process is completed for each new procurement. The primary product of this process is to define the pivotal business and technical issues affecting projects such as commercialization potential, regulatory acceptance of the emerging technologies, appropriate degree of cost sharing, procurement approach, as well as intellectual property and indemnification issues. Upon award, the Project Manager works closely with the award recipient to advance the knowledge base of the technology, leading to the ultimate goal of providing maximum benefit to the public through the deployment of advanced energy systems.

The NETL has a multi-year plan for improving NETL's project management skills. The goal of the plan is to provide training opportunities over the next five years for OPM Project Managers—the desired result being that 90 percent of OPM's Project Managers will be certified by the end of FY 2006. A series of formal courses were conducted during FY 2002. In addition to these formal courses, several short seminars were organized for those Project Managers taking the certification exam.

Onsite Research

Onsite research and development is a significant Laboratory asset. Approximately one-third of the NETL's staff, including Federal and contractor employees, are directly involved in onsite R&D. Through onsite R&D, the NETL develops and implements a comprehensive R&D portfolio that addresses critical programmatic needs, provides a rapid response capability, and serves as an unbiased technical resource to assess conflicting external research claims. Onsite R&D employees participate in the NETL product teams that have been formed for key R&D areas to define and develop programs, formulate competitive solicitations, review proposals and manage contracted R&D.

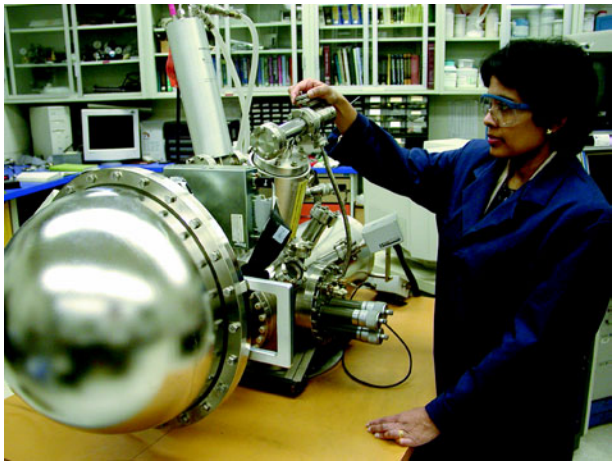
Onsite R&D at the NETL is led and managed by Federal employees, and implemented by Federal researchers supplemented by research associates from a number of universities and onsite contractor staff. The NETL plans and conducts state-of-the-art research to provide clean energy alternatives that are of critical importance to the Nation. Through onsite R&D, the NETL provides a "corporate R&D" function for the Office of Fossil Energy, including long-range exploratory research as well as enabling science for energy technologies. The NETL onsite R&D also provides key integration facilities for university collaboration, serves as a focal point for regional scientific initiatives, and provides technical leadership to support program development.

Onsite R&D is organized into six Focus Areas. Focus Areas are technical sectors in which the NETL envisions further growth and development to address emerging national energy issues. The Focus Areas include:

- ***Carbon Sequestration Science***—Works to establish the scientific basis for capture of carbon emissions from fossil-fueled power plants, and sequestration of carbon in media such as geological reservoirs and oceans.

- ***Clean Fuels***—Conducts research on clean fuels to meet the needs of the transportation sector, both near- and long-term, including removal of sulfur and other contaminants from fuels, and addresses the scientific issues related to potential future fuels, such as hydrogen.

- ***Computational Energy Science***—Uses mathematical simulations to better understand and predict the dynamics and operations of advanced energy and environmental processes and systems.



- ***Environmental Research***—Investigates environmental issues affecting the existing fleet of power plants, such as fine particulate and mercury emissions, use of combustion byproducts, and watershed science.

- ***Gas Energy System Dynamics***—Investigates gaseous-fueled power systems, such as gas turbines and fuel cells, and related enabling technology, such as combustion and electrochemistry.

- ***Vision 21 Advanced Power Systems***—Studies key technologies and components of future electric-power-generation systems such as gasification, gas cleanup, and energy conversion.

Scientific Leadership

Eminent scientists, serving as Focus Area leaders under the guidance of the NETL Associate Director responsible for onsite R&D, provide scientific leadership in the Focus Areas. The functions of the Focus Area leaders are to:

- Work with scientific and research staff, onsite R&D management, the Focus Area Steering Group, and appropriate product teams to develop research plans to address product needs and long-term research goals.

- Provide scientific leadership to achieve Focus Area objectives.

- Assess the "state-of-science" in relevant areas and develop proposals for future research.

- Lead Merit Reviews to ensure the relevance and scientific excellence of all research activities.

- Recruit scientific staff and develop research capabilities.

- Develop relationships and appropriate collaborations with scientific leaders in other organizations.

- Publish Focus Area research findings in appropriate venues.

Recent Highlights—NETL Onsite Research

- Established six Focus Areas to serve as a roadmap for NETL onsite research over the next five years.
- Sponsored a comprehensive merit review of all NETL onsite R&D by teams of nationally known scientific experts, and used the merit review results to guide research activities. This involved reviewing more than 90 research project proposals by 27 external experts from industrial laboratories, universities, and other Federal laboratories.
- Built strong partnerships between onsite researchers and regional universities, including Carnegie Mellon University, West Virginia University, University of Pittsburgh, and Pennsylvania State University. This includes a student partnership program involving 30 graduate students, and Research Associate/Research Fellow programs involving approximately 25 faculty and postdoctoral researchers.
- Received an R&D100 award for inventing a promising material to remove sulfur in advanced coal-power-generation systems.
- Significantly upgraded the MFIX multi-phase computer code, making it the world standard in multi-phase modeling.
- Designed and constructed a unique Ocean Sequestration Laboratory for carbon sequestration research that allows researchers to accurately duplicate conditions that exist in deep ocean environments.
- Found that certain synthetic zeolites have excellent CO_2 adsorption capacities and show preferential and high adsorption of CO_2 from gas mixtures at high pressure. In addition, a new type of CO_2 removal sorbent with excellent regenerability was also developed. This discovery will improve the economics of conventional CO_2 capture by reducing losses of expensive makeup chemicals.
- Led several national and regional workshops on carbon sequestration technology. Additionally, NETL scientists edited a special issue of the prestigious American Chemical Society journal Energy & Fuels that was devoted to carbon sequestration science.
- Perfected a technique known as time-lag modification, a method to produce stable low-emission combustion for turbines using natural gas fuel.
- Developed a method for activating nanotubes that increases their hydrogen storage capacity threefold, bringing nanotubes closer to DOE's target for hydrogen sorbents. The computational component of the effort was featured on the cover of Chemical and Engineering News.
- Received recognition by the Army Research Laboratory at Aberdeen Proving Ground for contributions to predicting crystallographic properties of energetic materials. These models have been distributed and used internationally and incorporated into software being developed by other researchers.
- Developed a photocatalytic process for converting methane to methanol and hydrogen.
- Developed, in conjunction with the University of Pittsburgh, a two-stage model for mercury removal using activated-carbon injection.
- Pioneered the application of remote sensing technologies as tools for the assessment of watersheds. Remote sensing allows scientists to rapidly locate and subsequently characterize all potential pollution discharge points, which can be extremely difficult otherwise because of aerial extent, rugged topography, and/or limited land access.

8.2 Functional Management

Acquisition and Assistance

The NETL accomplishes its mission, in part, through the solicitation, award, and administration of contracts, grants, and cooperative agreements for research and development, services, supplies, facilities, and equipment. The NETL manages nearly 1,100* active contracts and agreements with a total value exceeding $7.4 billion. Contract and patent law support is provided by the NETL Office of Chief Counsel.

The instruments and approaches used by the Acquisition and Assistance Division to accomplish our mission range from solicitations with specific, well-defined statements of work to broad-based solicitations seeking a multiplicity of technological approaches. The NETL has aggressively increased the number of awards to small and minority businesses. In FY 2001, approximately $271 million, or 23 percent, of the $1.177 billion spent on awards went to small businesses.

The goal is to improve productivity through a more customer-friendly, streamlined solicitation process, and to make it easier for external customers to submit proposals using electronic tools.

Financial Management

The NETL is committed to continually improving its financial-management practices and operations, striving to be a more cost-effective and efficient organization. Current activities include providing enhanced training opportunities to employees in DOE and Federal financial-management processes and actively participating in Departmental efforts such as the development and implementation of a new financial-management system (BMIS-Phoenix). Several members of the Financial Management Division have acquired or are pursuing Certified Government Financial Manager certification.

Financial management at the NETL ensures that the NETL's financial resources are properly controlled. All budgeting, accounting, and internal control responsibilities are conscientiously carried out. As a Government-operated Laboratory, our primary accounting system is the Departmental Integrated Standardized Core Accounting System (DISCAS).

The DOE Office of the Chief Financial Officer has approved the NETL-developed methodology for determining the indirect labor rates for work for others. While our rates are competitive, we are striving to reduce both direct and indirect costs. To further enhance financial management at the NETL, the Financial Management Division is divided into three financial areas, consistent with DOE Order 520.1—finance and accounting, budget and planning, and financial review. This separation of duties ensures that sound internal controls and oversight are in place.

The NETL's budget for FY 2002 is shown in tables 8 through 11.

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* Excludes in-house projects, agreement task orders, MOBIS contracts, technical work funded under purchase orders, CRADAs, as well as projects funded through Field Work Proposals at other national laboratories.

Human Resources

In addition to a highly skilled Federal staff of 593 employees, the Laboratory has 568 onsite support contractor employees performing a variety of professional, technical, administrative, and maintenance functions. A summary of our Federal and site-support contractor employee degree composition is provided in chapter 9, table 1.

The NETL is committed to affirmative action, cooperative labor-management policies, and family-friendly personnel practices and policies—all aimed at recruiting, appropriately compensating, and retaining a high-quality, productive, and diverse workforce. Key goals are to:

- Fully utilize all available Federal appointing authorities to identify and recruit a high-quality and diverse group of research scientists and engineers, including faculty and student appointments.

- Refine the process used to identify training requirements and priorities to ensure that NETL employees have the knowledge, skills, and abilities necessary to meet current and new mission objectives.

To attract first-class scientists and engineers, the NETL utilizes recruitment tools such as recruitment bonuses, increased pay for superior qualifications, and payment of first-post-of-duty travel. In addition, faculty and student appointments are provided through (1) the Intergovernmental Personnel Act, (2) programs with the Oak Ridge Institute for Science and Education, the National Research Council, and University Partners, and (3) the Student Career Employment Program.

NETL management utilizes workforce planning to develop and sustain an excellent, flexible, skilled, and diverse Federal workforce that effectively supports the NETL's mission. Federal and contractor staffing projections are identified in chapter 9, table 4.

The NETL actively supports and encourages employee development. Training opportunities are provided for employees at all levels and prioritized by accomplishment of mission objectives. The NETL reimburses college tuition costs, and provides flexible work schedules for employees to attend college classes. Employee participation in the Department's special leadership programs is also encouraged.

We have initiated several innovative practices to promote the well-being and productivity of our workforce. Specifically, we have implemented a performance management system that links individual performance evaluation criteria and work goals to organizational goals and rewards the organization for meeting mission-related institutional goals.

The NETL fully supports "family-friendly" policies. Our employees have the opportunity to participate in flexible work hour, alternate work schedule, and telecommuting programs, and to earn credit hours. A daycare facility is available at the Morgantown site and one is planned for the Pittsburgh site. Both sites have active health and exercise facilities open to all employees. The Federal Government has excellent benefits, including health and life insurance, as well as Federal retirement and thrift savings plans.

Equal Employment Opportunity/Workforce Diversity

The NETL is committed to increasing the representation of women and minorities in our workforce, as well as in the job applicant pool (especially for underutilized groups). The NETL initiated a Minority Mentoring Intern program that is targeted to bringing minority students into the Federal Government through the Student Career Employment Program (SCEP) which permits noncompetitive conversion of SCEP students to permanent positions once they have completed the required education and work experience. In FY 2002 more than one-half of our new hires and transfers have been minorities and/or women. A summary of our new hires in FY 2002 is provided in chapter 9, table 2.

The term "workforce diversity" encompasses a broader set of issues than the traditional focus of Affirmative Action and Equal Employment Opportunity (EEO) compliance. For the NETL, diversity means respecting the differences in people and using their differences to create a successful and creative work environment. We strive to improve the quality of our workplace through a policy of zero tolerance for harassment based on race, sex, color, religion, gender, national origin, age, disability, and/or sexual orientation. A summary of our Federal workforce statistics is provided in chapter 9, table 3.

The NETL has an active EEO program that recognizes and celebrates special emphasis programs that are open to both Federal and contractor employees. Volunteer EEO counselors are trained and available to employees for consultation on workplace issues. An Employees with Disabilities chairperson and a Selective Placement coordinator deal with issues concerning disabilities and reasonable accommodation. A Federal Women's Program Advisory Council meets periodically to address women's issues at the NETL.

Support-Service Contractors

The NETL support-service contracts contain provisions requiring (1) human resource management programs similar to those applying to the Federal staff be enacted and (2) action to improve the diversity of the contractor workforce be taken. Each contract also specifies areas of support and defines authorized labor categories—provisions designed to ensure that contractor staffing complements rather than duplicates or conflicts with Federal staffing patterns. This clear definition of roles optimizes appropriate allocation of human resources and allows both Federal and contractor management to focus recruiting and retention programs on employees possessing clearly defined knowledge, skills, and abilities critical to the advancement of the Laboratory. Support-service contractor staffing statistics are presented in chapter 9, table 3.

Information Resource Management

Information management at the NETL includes computing resources and software for telecommunications, scientific research, administrative functions (printing, library services, photography, writing, and

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editing), records management, and document control. The goal of information management is to maximize the ease and effectiveness with which information is acquired, created, modified, stored, retrieved, and applied, both within the NETL and with our partners in government, academia, and the private sector. Our strategy is to:

- Maintain an efficient, standards-based infrastructure for communications, computer networking, and information systems.
- Continually enhance services that facilitate internal and external information exchange.
- Conduct education programs that upgrade the computer literacy and skills of our employees.
- Maintain strong core competencies in emerging and current information technologies.
- Enable timely deployment of information systems and services tailored to mission needs.
- Evaluate emerging information technologies through aggressive use of demonstrations and pilot projects.

These strategies for information management focus on our needs for secure, high-performance telecommunications and networking infrastructure, and high-quality laboratory-wide information systems. The Laboratory implements these strategies based on strategic initiatives developed and documented in a multi-phase, 3-year plan for NETL's information technology (IT) strategic direction. This plan identifies strategic initiatives and resources required for implementation, ensuring that IT infrastructure and technical capabilities keep pace with evolving NETL requirements. At the core of these activities is adoption of new technologies to provide access to cost-effective IT solutions for NETL users.

The NETL uses an enterprise architecture process for managing IT architecture consistent with organizational mission and goals. The enterprise architecture team gathers, evaluates, and prioritizes IT projects. Its key function is to make recommendations to senior management on where to invest available resources. This process ensures that the collective needs of the Laboratory are considered when making decisions to change the existing IT architecture or investigate new technologies.

The heart of the NETL network infrastructure is evolving to a high-speed (Gigabit Ethernet), robust telecommunications network that keeps pace with the bandwidth demands of advanced administrative and computational technologies. Increased use of advanced technologies like virtual reality and desktop video will require larger amounts of bandwidth than can be achieved by upgrading the existing telecommunications system. Near-term plans are to explore the use of wireless local-area-network technology to provide cost-effective services to remote offices and labs.

Administrative Computing

The NETL is supported by an integrated, interoperable, secure, administrative computational system. We will continue to improve employee access to information needed for day-to-day operations. Web technologies are being applied to increase desktop access to information and applications that reduce paperwork, with an emphasis on decreasing costs and increasing end-user efficiency. We make extensive use of our Intranet to facilitate dissemination and retrieval of information, and to enhance productivity.

The NETL actively deploys standards-based systems and advocates the use of off-the-shelf products when possible. The majority of application development is in the deployment of database technologies—technologies that enable warehousing, ensure that information management systems support timely and effective decisionmaking, and allow for exploration of data for analysis and forecasting.

Scientific Computing

Scientific computing is supported by a combination of resources. Most small- and mid-scale simulation and modeling studies are performed on SGI or Intel-based workstations. Mid- and large-scale computing is performed with parallelized codes on Linux-based cluster computers.

The NETL has fostered a relationship with the Pittsburgh Supercomputing Center (PSC) to obtain advanced computational capabilities. The arrangement with PSC allows the NETL researchers access to advanced computing capabilities at less cost and with less risk than would otherwise be possible. NETL researchers and contractors have access to these powerful computing resources through a scientific computing consortium arrangement among the NETL, the PSC, Carnegie Mellon University, the University of Pittsburgh, and West Virginia University.

The NETL has substantial capabilities for visualization of scientific results, experimental projects, and virtual plants. These include high-end workstations driving Elumens Vision Stations, a dual-projected-wall visitors center and a walk-in virtual environment to provide complete immersion in scientific simulations or virtual plants.

Plans are to expand the use of Internet-collaboration technologies that enable us to work in synergy with other Laboratories and educational entities. These technologies will make it easier for geographically distant collaborators to work together by allowing researchers in distant locations to display simulations, text, graphics, engineering drawings, computer-aided-drafting models, and animation sequences, and to analyze data, as if the researchers were colocated. The NETL will continue to upgrade computational facilities to maintain state-of-the-art simulation and modeling capabilities.

Site and Facilities Management

Effective management of our physical resources—the buildings, equipment, and infrastructure on the NETL sites—is key to successful mission accomplishment.

The NETL consists of four sites located in Morgantown, West Virginia; Pittsburgh, Pennsylvania; Tulsa, Oklahoma; and Fairbanks, Alaska. The Morgantown and Pittsburgh facilities are 65 miles apart and cover 131.6 acres and 59.7 acres, respectively. These two sites have a total of 92 permanent or temporary buildings and over 800,000 square feet of building area. The Tulsa facility, involved primarily in technical program management functions, is housed in leased office space. Table 5 in chapter 9 summarizes information related to our facilities at the sites.

Facilities and Infrastructure Vision

Achieving world-class Laboratory status requires state-of-the-art facilities. This can be accomplished only by continually revitalizing existing facilities, identifying interim facilities to meet current needs, and constructing or renovating new mission-driven facilities. NETL's vision is to provide a scalable, flexible, and sustainable infrastructure to meet the growing and diverse needs for facilities and equipment.

Facilities and Infrastructure Goals

NETL's Site Operations Division (SOD) is assigned the role of developing a facility plan that assures the mission-driven requirements are met while maintaining and operating the physical plant in a safe and reliable state. Six goals are key elements of the facility plan:

1. ***Strategic Acquisition***—Through partnership with research customers and stakeholders, we will identify, acquire, and review assets required to meet current and emerging needs.

2. ***Return on Investment (ROI)***—We will leverage resources and requirements to maximize the use of available resources and ROI. ROI may include a combination of asset costs (materials, design, labor) and life-cycle environmental impact costs, including those incorporating advanced building technologies.

3. ***Delivery of Capital Investment***—Capital investment will be adequately planned, managed, and controlled according to an approved plan.

4. ***Strategic and Life-Cycle Plans***—Facility strategic and life-cycle plans and renovation schedules will be maintained, for the purpose of keeping the design current.

5. ***Utility Infrastructure***—The NETL will design and implement a strategy to provide a cost-effective, long-term utility infrastructure capable of supporting DOE's science and technology mission.

6. ***Asset Disposition***—Assets that have reached or are beyond their useful life will be identified and dispositioned in accordance with DOE Property Management Directives.

Facility Planning Process

The facility plan, which is updated yearly to align with this Laboratory Institutional Plan in order to support the direction of research and development, is a guide for NETL investment decisions for maintaining best value from facilities and land. The NETL's senior management uses this plan annually to approve facility investments or divestitures. The plan provides senior management with updated information on priority facility and infrastructure requirements, annual investment projections, and progress toward achieving the desired goals.

When planning for revitalization of facilities and infrastructure, needs are ranked using the Department's Facilities Information Management System (FIMS) prioritization rating criteria. Facility needs and projects are individually evaluated and ranked using FIMS subcategory areas of health and safety, environmental and waste management, safeguards and security, and in-house research requirements. The highest scoring projects are then included in the annual facility plan as future priority projects.

Functional Requirements

To attract and support high-quality staff, the NETL strives to provide a productive working environment that encourages creativity, interaction, and collaboration. Design opportunities for the worker environment include state-of-the art computing capability; sufficient office, laboratory, and conference space to allow for planned and ad hoc conversations and meetings; and a platform for showcasing NETL-developed technologies. During the design of new facilities and renovations of existing ones, environmental and sustainability factors are incorporated. These factors take into consideration the siting of new facilities, selecting environmentally preferred products for construction materials, using onsite renewable energy sources, and disposing of waste in compliance with ISO 14001 requirements.

In selecting facility equipment, operations and maintenance cost is a primary driver. Analysis is based on life-cycle costs rather than solely on initial equipment cost. Safety, health, and security infrastructure costs are also key to minimizing life-cycle costs.

Current State of Facilities and Infrastructure

Facilities at the NETL have suffered from years of insufficient funding for infrastructure improvements. Many of our laboratory and office facilities are old and inefficient; they need to be upgraded to meet modern industry standards. Of the 71 Government-owned, permanent buildings on our sites, four are in "poor" condition (i.e., incapable of supporting our research mission requirements). Of the 21 temporary buildings (mobile trailers), 15 are beyond repair and need to be eliminated. In addition, 18 permanent buildings will reach the end of their expected useful life span of 40 years within the next five years. The average age of the NETL's permanent buildings is 27 years. A condition assessment of the NETL's buildings (including temporary buildings) is shown in chapter 9, figure 2. The replacement plant value for the NETL's facilities at Morgantown and Pittsburgh is $455 million as shown in chapter 9, table 6.

Laboratory, Site, and Facilities Plans

In addition to general upgrade needs, our laboratories need to accommodate growth in the R&D Focus Areas. Within two years, many current research projects are expected to come to an end as the Focus Areas evolve. Improvements to both office facilities and laboratory space are required to support each Focus Area.

The cornerstone of the NETL's facility plan is the construction of two new buildings—one in Morgantown and one in Pittsburgh. Each multi-story building will contain 48,000 square feet of offices and computational research laboratories, and will accommodate 135 technical personnel. The new buildings will incorporate state-of-the-art research-and-computational equipment. They will also include energy- and maintenance-efficient systems that minimize operating costs. The decision to replace rather than renovate existing facilities is based on an analysis that shows that it is more cost-effective to construct new energy-efficient buildings, designed to accommodate the needs of the NETL's new program areas, rather than to remodel existing facilities. In addition, there are no buildings at Morgantown that can be renovated to accommodate the offsite employees occupying leased space.

At Morgantown, the new building will house the Gas Energy Systems Dynamics Focus Area and the Computational Energy Science Focus Area. In Pittsburgh, the new building will house the Carbon Sequestration Science and Clean Fuels Focus Areas. The buildings will provide attractive entrances for visitors to the Nation's only Federal laboratory dedicated to fossil energy research.

The plan also includes extensive renovation of a number of existing office and laboratory buildings. The renovated buildings will provide laboratories to meet an expanded mission for controls and sensors research, the Clean Coal Power Initiative, natural gas infrastructure reliability, Vision 21, and watershed technology research.

Equally as important, the physical plant infrastructure at both sites will be upgraded. Key improvements are planned for the electrical system, compressors, process-water-distribution system, and utility conduits.

A total of $77 million is needed over the course of seven years to implement the NETL's New Construction and Renovation Plan. The funding profile for this capital investment is depicted in chapter 9, table 7. The $77 million comprises the sum of the New Building Support Projects (demolition, infrastructure construction, and so on) and the New Building Construction lines in that table. Funding received to begin implementation of the plan in FY 2002 was $11 million.

The new buildings planned for the Morgantown and Pittsburgh sites will replace laboratory buildings and modular offices that are at the end of their useful life and those in need of significant renovation. These structures cannot be cost-effectively converted to support new research activities. The elimination of modular offices in Morgantown and mothballing of some large, outdated laboratory buildings in Pittsburgh will reduce the NETL's overall operations and

maintenance costs. The $77 million investment to upgrade the NETL's facilities will be recouped in 20 years. Some of the technologies that will be utilized where feasible include Energy Star-compliant materials and equipment, integrated photovoltaics, intelligent building systems, high-efficiency centrifugal chillers, smart windows, renewable materials, xeriscape (an approach to saving water in landscaped areas), and natural-gas fuel cells. When implemented, the NETL's New Construction and Renovation Plan will result in a national laboratory with state-of-the-art facilities.

General Plant Project funding for FY 2002 is $2 million, or 0.22 percent of the NETL's current replacement value. Our analysis of the Laboratory physical plant shows that a General Plant Project funding level of $6 million per year, or 1.3 percent of the NETL's replacement plant value, is needed to adequately maintain the NETL's facilities. This higher level of funding, as shown beginning in FY 2005 in chapter 9, table 7, is consistent with industry standards for maintaining laboratory facilities.

Assets Management

The Property Management program assures effective management, acquisition, utilization, and disposition of Government property (real and personal property, motor vehicle management, etc.) in the possession of NETL employees and its contractors, consistent with applicable regulations and policies. The program function is to ensure adequate physical protection and control of Government property, proper utilization of Government property, and excessing of property that is obsolete or no longer needed.

Realty specialists conduct annual utilization reviews, ensure the Department's Facility Information Management System (FIMS) and Management Analysis Reporting System (MARS) are updated with current information, and approve all actions required by the Life-Cycle Asset Management (LCAM) Order.

Energy Management

The NETL's energy management initiatives are implemented consistent with a Comprehensive Energy Management Plan (CEMP) that includes the requirements of the updated DOE Order 430.2A as well as the requirements of Executive Order 13123. The NETL's energy management program is directed toward reducing energy consumption, reducing operational costs, protecting the environment, and providing leadership by adopting emerging energy technologies. Since 1985, we have reduced energy consumption by 45 percent. In addition, the purchase of electric power through a consortium of Government agencies has reduced costs by 6 percent.

The NETL has begun the process of attaining ISO 14001 environmental performance certification. One of the environmental aspects identified for improvement at the NETL is energy and fuel usage. This aspect comprises six targets: improving the energy management program, reducing energy use per square foot, increasing purchase of electricity from clean sources, reducing petroleum consumption, acquiring more alternative-fuel vehicles, and increasing the usage rate of alternative fuel in vehicles.

The NETL has also applied for energy efficient retrofit funding and energy audit funding from DOE's Federal Energy Management Program (FEMP) office and has been successful in obtaining funding. The NETL has completed the energy audit and a lighting retrofit project for the daycare center at Morgantown. The latest retrofit project to be approved for funding from FEMP will involve removal of two ozone-depleting chillers from an analytical research building.

Integrated Environment, Safety, and Health Management

The NETL is committed to protecting its Federal and contractor workers, visitors, the public, and the environment by integrating appropriate environment, safety, and health (ES&H) practices into all work processes. The NETL is currently focusing on implementing (1) DOE's commitment to the core functions and guiding principles of Integrated Safety Management (ISM), (2) the Office of Fossil Energy's commitment to ES&H excellence (as referenced in its *Commitment to Environment, Safety, and Health*), and (3) a certified environmental management system (EMS).

Current Conditions

The NETL sites located in Morgantown and Pittsburgh are primarily industrial in nature, although some portion of each site is designated as office environment. The Tulsa site is exclusively an office environment. The laboratory portion of the Morgantown and Pittsburgh sites include pilot- and bench-scale research facilities. Typical research-related hazards could include high temperatures, high pressures, electrical systems, chemicals, moving machinery, and construction activities. Other sources of risk may include indoor air quality, the presence of lead or asbestos, and physical hazards (e.g., slips, trips, and falls).

Based on the collection and analysis of injury and accident information, the following trends have been observed at the NETL: (1) the majority of injuries continue to be the result of unsafe acts rather than unsafe conditions; (2) the major specific causes of injuries continue to be improper material handling as well as slips, trips, falls, and repetitive motion injuries; and (3) the majority of injuries result in sprains and strains and are a result of overexertion affecting the back.

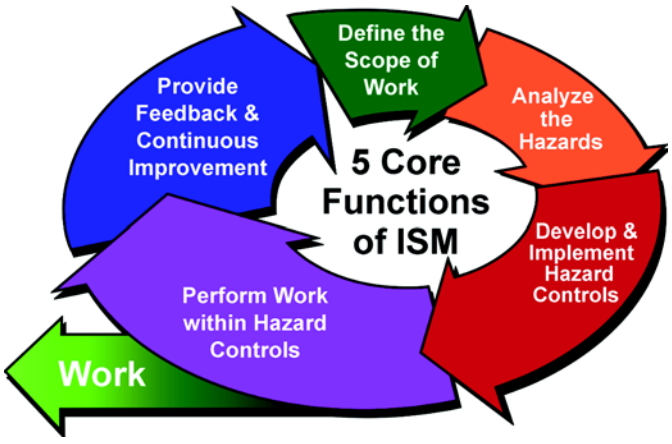
Planning

The NETL has a corporate commitment, which is instilled in the employee culture, to improve the effectiveness and efficiency of ES&H through its practice of ISM and its commitment to environmental excellence and continual improvement. Current continual improvement activities include attaining International Organization for Standardization (ISO 14001) certification for the NETL's onsite operations. The NETL uses the five-year ES&H Management Plan as its primary planning, budgeting, and prioritizing tool.

Achieving a Certified Environmental Management System (EMS)

The NETL is currently focusing its efforts on implementing the Lab's comprehensive environmental policy under its EMS. The acronym "PRISM" summarizes the key aspects of this policy.

Through Executive Order 13148, *Greening the Government Through Leadership in Environmental Management*, the NETL is required to have a "certified" environmental management system (EMS) in place by 2005. As a result, the NETL has adopted "ISO 14001"—the internationally accepted standard for environmental management systems—as its structure for managing operations and improving environmental performance.



As an integral step in becoming certified, the NETL has conducted reviews of all onsite projects, facilities, and operations to determine their significant environmental aspects. Specific objectives and targets have been developed to address these environmental aspects. The NETL is now implementing Environmental Management Plans (EMPs) to achieve these objectives and targets. As a final step in attaining ISO 14001 certification, the NETL will undergo an external certification audit conducted by an approved registrar.

Many of the NETL's activities identified for FY 2003 and beyond have evolved directly from implementing EMPs designed to meet objectives and targets associated with managing the NETL's environmental aspects. These objectives and targets are largely based on achieving the DOE's pollution prevention and energy efficiency leadership goals (dated November 12, 1999).

Key Aspects of the NETL's Environmental Policy

- **Pollution Prevention** at the NETL focuses on source reduction. This includes eliminating the generation of pollution through procurement initiatives, system design, facility operations, and efficient work practices.
- **Regulatory Compliance** at the NETL means all employees are aware of, and comply with, all applicable environmental regulations.
- **Improving Continuously** is key to successful implementation of EMS/ISM. The NETL seeks to improve its environmental posture and enhance worker safety.
- **Safety Analysis and Review Systems** (SARS) help the NETL to identify, analyze, and minimize health, safety, and environmental hazards in the workplace.
- **Minimizing Waste** is key to the NETL's "waste-prevention" culture. Waste generation is avoided when possible, waste is recycled when feasible, and waste is disposed of only as a last resort.

Specific objectives assigned to managing NETL's significant environmental aspects include:

- ***Waste Generation, Management, and Disposal***—(1) To reduce non-hazardous (e.g., paper, cardboard, food wastes) and hazardous (e.g., laboratory chemicals) wastes; (2) to increase recycling of the NETL's non-hazardous wastes.
- ***Energy and Fuel Usage***—(1) To reduce the NETL energy consumption through life-cycle cost-effective measures; (2) to increase the NETL's purchase of electricity from clean sources; and (3) to reduce annual petroleum consumption for the NETL's vehicular fleet.
- ***Hazardous Material Procurement, Consumption, Storage, and Release***—To reduce amounts of hazardous materials procured, received, and stored at the NETL.
- ***Industrial Wastewater Treatment Facility Operations/Discharges***—To reduce or eliminate violations of and maintain compliance with Industrial Sewer Use Pretreatment Permit requirements.
- ***Air Emissions***—(1) To reduce use of ozone-depleting substances; (2) to reduce generation of greenhouse gases; (3) to increase use of alternative fuels in vehicles; (4) to decrease air emissions of toxic compounds; and (5) to decrease air emissions from painting operations.
- ***Toxic Chemicals and Energy Releases***—To decrease risk levels to the environment and to workers associated with chemical or energy releases (or potentials to release) from the NETL's chemical handling and dispensing facility.

- ***Surface Water and Storm Water Discharge***—To better understand the impacts of the NETL and nearby offsite activities on surface water and storm water resources.

- ***Raw Materials Usage***—To purchase EPA-designated items with recycled content.

- ***Noise***—To reduce fence-line noise levels attributable to the NETL.

- ***Land Use***—To conserve and enhance the NETL's "non-industrial" land by maintaining or increasing the percentage of land used for non-industrial purposes, and increasing the quality of non-industrial land over time in terms of ecological benefit, utility, and diversity.

Processes and Metrics

To fully integrate ISM principles into the NETL culture and workplace, a series of ISM-related management processes has been developed, implemented, and documented in our directives systems. These processes include standards identification and maintenance, assessment, performance measures, corrective action, feedback, lessons learned, continuous improvement, and training.

To more fully implement line-management accountability of operations, assessments are routinely conducted to collect ES&H performance information, identify deficiencies and improvement opportunities, and more fully implement line-management accountability of operations. Line-management walk-through inspections are conducted monthly, and all onsite facilities and operations are reviewed at least annually.

The following high-level metrics are being used to assess progress in meeting the NETL's ES&H, ISM and EMS goals and commitments:

- ***OSHA Statistics***—The OSHA recordable case rate, lost work day case rate, and cost index are being tracked as lagging indicators of the NETL's safety and health performance.

- ***Environmental Management System (EMS)***—The achievement of milestones contained in the NETL's Environmental Management Plans (EMPs), the achievement of EMS targets, and the number of environmental releases and non-compliances with environment permit requirements are being tracked as lagging indicators of the NETL's environmental management system performance.

- ***GPRA Requirements***—The achievement of milestones contained in the NETL's 5-year ES&H Management Plan is an indicator of the NETL's ES&H planning and execution effectiveness for its core and compliance-based ES&H programs.

- ***ES&H Preventive and Corrective Actions***—The number of preventive actions and the number of urgent and serious corrective actions are indicators of future and past ES&H performance, respectively. Performing these preventive and corrective actions within a specified time frame is an indicator of the timeliness of implementation processes at the NETL.

- ***Independent Program Reviews***—The number of independent ES&H program reviews is a leading indicator of future ES&H performance and acts as a major generator of ES&H improvement opportunities.

- ***Training Performance***—The requirement that all employees take at least eight hours of ES&H training is a leading indicator of improved ES&H performance.

Security, Intelligence, and Nonproliferation

The NETL is classified as a property-protection facility with specific emphasis on the protection of employees and visitors, Government-owned property, and information generated by employees, contractors, partners, and stakeholders. To efficiently administer our programs, safeguards and security practices are integrated into all work processes under the guidance of specialists in physical security, cyber security, property management, foreign travel and assignments, information security, and export control, matrixed to a central management function. Security systems at the NETL include physical-protection systems, protective forces, property control, and administrative policies and procedures.

The primary safeguards and security objectives are to:

- Establish safeguards and security processes consistent with an unclassified property-management Laboratory and integrate these processes into the culture of the workforce.
- Institutionalize protocols that distinguish and track critical and sensitive information at the NETL to prevent the release of such information.
- Maintain an appropriate balance between (1) the protection of persons, property, and information and (2) the legitimate need for free and open collaboration as well as access to laboratory facilities and NETL professional employees by research associates, including citizens of the United States and foreign nationals.
- Maintain state-of-the-art cyber security mechanisms and countermeasures to ensure the confidentiality, integrity, and availability of DOE data systems that process, store, or transmit information.

Physical Security

A support-service contractor provides protective force operations at the NETL's Pittsburgh and Morgantown sites. The Western Area Power Administration provides security support services for the Tulsa site. The Laboratory has formal arrangements with local law enforcement agencies should their services be required.

Information Security

The NETL has an information security program that institutionalizes procedures for ensuring that intellectual property, including data associated with contracts and other agreements, such as CRADAs or Memoranda of Understanding, is protected from inadvertent release and subjected to export control and patent disclosure reviews.

Cyber Security

The NETL cyber security program is designed to establish accountability and maintain effective cyber security mechanisms and countermeasures to ensure the confidentiality, integrity, and availability of DOE data systems that process, store, or transmit information. The goal of the cyber security program is to provide a state-of-the-art cyber security capability that protects information in accordance with Federal requirements and DOE mission needs.

Foreign Travel

The NETL's missions require that some NETL personnel travel internationally. The NETL foreign travel program is a vital outreach resource that allows the NETL to transfer U.S. energy and environmental technology information on its programs and to collect information important to further our ongoing programs and Government policy objectives.

The NETL recognizes that this travel (1) is important to the U.S. economic security and (2) promotes U.S. technology, equipment, and services developed under Federal programs. Through careful planning and management reviews, the NETL ensures that all foreign travel is conducted in an efficient, effective, and secure manner.

Foreign National Visits and Assignments

The NETL Foreign National Visits and Assignments Program is dedicated to conducting all foreign visits and assignments in a manner consistent with U.S. and DOE national security policies requirements, including export control laws and regulations. International cooperation and collaboration are important elements in the effective planning and implementation of many of the Department of Energy's programs. The NETL and its international partners benefit from the exchange of information that results from a dedicated management process, one that ensures foreign visits and assignments are (1) used to advance the program objectives of DOE and (2) are consistent with U.S. foreign and nonproliferation policy, international energy policy and agreements, and national security policy and objectives.

8.3 Management Processes

Labor-Management Partnership

The Union and Management work together through a Labor Management Partnership Council (LMPC) to foster a quality work environment for employees and to more efficiently accomplish the NETL mission. While neither Management nor the Union waves its inherent rights and duties, both recognize the potential benefits in operating as partners in which each has equal status and a certain independence, but also an implicit or formal obligation to the other to work together to more effectively achieve shared objectives.

The Union and Management, through equal representation on the LMPC, have agreed to discuss issues, share information, and work to solve problems as partners in the most constructive manner possible. The intent of joint problem solving is not comanagement, but to seek input from the Union at the appropriate stage before final decisions are made by Management. Joint problem solving at the appropriate stage shows good faith efforts between the partners, allows for more informed decisions, and expedites impact and implementation negotiations.

The ranking senior officials of the two American Federation of Government Employees Unions also meet with the NETL Director and Deputy Director for Operations on a quarterly basis for executive discussions on Labor/ Management issues.

Approach to Planning and Measurement

The NETL uses a multi-level approach to planning program support activities. Our Institutional Plan forms the foundation that other plans build upon. The strategic directions in the Institutional Plan are reflected in Operations Plans prepared at the Office and Division level as well as in Product Plans, which list RD&D goals and objectives. Individual performance goals for employees are developed annually based on Operations and Product Plans. Using this approach, employees see the link between their individual goals and the strategic direction of the Laboratory.

The NETL has established high-level metrics to track key Laboratory processes that are critical to the success of our mission. Progress against these high-level metrics is reported quarterly, discussed by senior management, and posted on our Intranet for all employees to see. This approach to planning, defining, and reporting metrics helps ensure that we measure, track, and respond to activities critical to achieving success.

On the program level, our internal planning processes are closely linked to planning activities conducted by the Office of Fossil Energy, the Office of Environmental Management, and other DOE offices. We participate in a number of program-planning forums within the Department.

Communications

We support DOE's commitment to communication; we embrace the objective of working with customers and stakeholders in an open, frank, and constructive manner. We are committed to increasing our employees' and the public's awareness of our activities, programs, and successes.

Internally, we inform NETL employees of our mission activities and successes via the NETL Intranet, a monthly employee newsletter, an e-mail network, quarterly all-employee meetings, and an electronic Grapevine system whereby employees can anonymously submit questions to management.

Integral to our success is the ability to communicate to regional and national stakeholders about NETL activities and successes. Various informational tools have been prepared to solicit input from, stay in touch with, and inform external stakeholders about our activities. For example, "fact sheets" and other print materials are prepared to communicate our mission and technical results to the public. Other examples are the newsletters distributed by the Petroleum Technology program. The NETL Web site provides information to our Internet audience, describing the organization, its objectives, and procurement opportunities. Our main Web page, which lists media and public-information releases, is an effective tool for describing new activities and events. A database of outreach publications is maintained in the publication section. Public news releases are showcased in the NETL "News Room." This virtual newsroom is updated weekly with information that is not time-sensitive.

We are particularly interested in promoting open communication with those living near our facilities. We hold quarterly meetings with Community Interest Groups that were formed in South Park (Pittsburgh) and Suncrest (Morgantown). These meetings provide a forum for community leaders, local government officials, members of the public, and NETL representatives to discuss issues of mutual interest. The Community Interest Group meetings help us to maintain good relations with local communities, keep them apprised of our activities (particularly onsite activities), and reassure residents of our responsiveness to community needs.

Educational and many industrial institutions located in the regions around the NETL sites have long been involved with energy and environmental technologies. Regional institutions are leaders in the research, development, demonstration, and deployment of advanced energy technologies. The capabilities of these institutions complement the NETL's expertise in energy and environmental research. Thus, the region offers many opportunities to collaborate on programs.

The NETL is working to increase the number of collaborative projects we have with regional universities. Joint appointments and shared resources can help the NETL and the universities strengthen our respective research programs. For example, we formed a partnership, called the Super Computing Science Consortium to establish a high-speed data network in southwestern Pennsylvania, foster closer collaboration among regional research institutions, and give the NETL access to a high-speed computational facility. The network, mentioned under the Scientific Computing section, is termed INNOVA-Link. It provides data, video, and voice communication connections among four participants: The NETL, Carnegie Mellon University, WVU, and the Pittsburgh Supercomputing Center (PSC). Although not connected to INNOVA-Link, the West Virginia Governor's Office of Technology is part of the consortium.

We also collaborate with regional-development offices. Through involvement in a project conducted by the West Virginia Development Office (WVDO), two compressed natural gas vehicle refueling stations are being installed to support fleets of alternative-fueled vehicles that travel the Interstate-79 corridor between Pittsburgh, Pennsylvania,

and Charleston, West Virginia. Related activities involving the Pittsburgh Clean Cities organization are planned to increase the use of alternative-fueled buses traveling to the Pittsburgh International Airport. These projects familiarize the region with alternative fuels and speed their broader acceptance. Such acceptance also provides a significant benefit to our major initiative in Clean Fuels.

Our employees have forged successful partnerships with local and regional Clean Cities and Rails-to-Trails initiatives. They also serve on local and regional economic development, professional, scientific, and engineering boards, and participate on State-wide and regional technology councils. Periodically, we host a public open house at the Morgantown and Pittsburgh sites.

Partnership Development

We seek out ways to transfer the results of NETL-supported RD&D—knowledge and know-how—to industries and small businesses that can use it to solve problems and create commercial activity. NETL researchers and those with whom we conduct cooperative research have over 500 active patents. Collectively we have published over twice that many technical papers and reports. In addition, NETL personnel and their many thousands of professional contacts are available to answer inquiries. This represents a wealth of knowledge and know-how available to those in need of an energy or environmental solution.

Technology transfer, in the NETL context, is traditionally defined as the process by which existing knowledge, facilities, and capabilities developed under Federal R&D funding are utilized to fulfill public and private needs. Although this process can be very simple or quite complex, it basically involves a technical resource (e.g., Federal laboratory), a user (e.g., small business), and some interface connecting the two. We have come to believe that it is the quality of this interface that is crucial to success.

The NETL seeks businesses and entrepreneurs interested in incorporating the knowledge and know-how we have accumulated into new or improved energy- or environment-related products. The major thrust of our approach is the focus on the market versus the technology. By focusing on the needs of those working in the marketplace, we are better able to help solve market problems and identify opportunities, rather than trying to force a technology into the marketplace.

In practice this involves a great deal of interaction with economic development organizations, business associations, entrepreneurial groups, universities, and individuals—listening to their problems and bringing those problems back to the NETL to seek matches with our knowledge and know-how. To ensure that this is done effectively, we use a variety of approaches, including knowledge management techniques, and are still working to develop the necessary tools and skills.

This new market focus is also working its way into the traditional tools of the technology—transfer trade—contracts and financial assistance agreements, Cooperative Research and Development Agreements (CRADAs), Contributed Funds Agreements, and licensing agreements. Our goals are to simplify and streamline these processes to make them "friendlier" to small businesses and flexible enough to assist entrepreneurs.

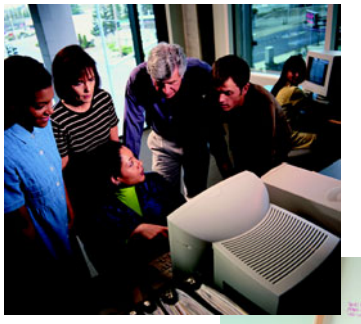
One example of a project where technology transfer is built into each activity is the Consortium for Premium Carbon Products from Coal. West Virginia University (WVU) and Penn State University coordinate this NETL-funded activity that has a membership of private sector concerns interested in commercialization. The consortium investigates non-fuel uses of coal, including production of coke and other premium carbon products that will reduce

dependence on petroleum in a broad range of industries (e.g., the electronics, transportation, chemical, and pharmaceutical industries). Some results of this collaboration include:

- Invention of carbon foam (WVU with commercial involvement of Touchstone Research).
- Development of a process for water purification using regenerative, granulated, activated carbon (Penn State University and Cincinnati Water Works).
- Manufacture of carbon fibers from coal more economically than was done traditionally using oil (Merck Corporation).
- Production of precursors for coke, pitch, and fibers using a solution of coal (WVU).

Educational Support

Educational institutions are a major focus area of our activities. Over 200 of our extramural research projects, valued at $411 million, are with academic institutions. We participate in the DOE Historically Black Colleges and Universities/Other Minority Institutions (HBCU/OMI) education exchange for students and professors.



We also contribute to our communities through educational initiatives. We provide experts to speak to local colleges, universities, conferences, and meetings. We have established a visiting professor program with five local universities and colleges. Through this exchange, local university professors benefit by working in an expanded scientific environment, and we gain from the expertise of these individuals.

On the elementary and secondary level, we participate in numerous activities. Our objectives are to increase emphasis on science, math, and technology and improve the quality of math and science teachers. We participate in the Adopt-a-School program in Tulsa organized by the Tulsa Chamber of Commerce. NPTO has adopted an elementary school with 14 percent Native American students. Activities include presenting oil-education programs, talking to students about careers, organizing Native American week, helping teachers and students with science projects, organizing a science fair, tutoring students in math and science, and organizing and conducting tours of various industries.

The NETL sponsors many activities that enable students to visit our research facilities to see firsthand how scientific research is conducted. Students get a glimpse into the daily activities of a research laboratory and the potential for careers as a chemist, physicist, engineer, biologist, or mathematician. We host "Take Your Children to Work" day at all our sites. Our "Cool Science" Web page provides information for students and teachers; we participate in programs to loan educational materials to local schools; and our scientists and engineers visit schools, giving demonstrations and participating in "Read Aloud Days" and "Career Days."

Other examples of educational activities include:

- Workshops conducted by the NETL employees for "Project AMPLE Extended" sponsored by Fairmont State College—a seventh grade science and math camp.

- Educator in the Workplace—teachers working in our laboratories for three weeks learning about lasers and developing lesson plans for presenting new information in the classroom.

- Science Bowls in Oklahoma, Pennsylvania, and West Virginia—a national competition designed to increase emphasis on science, math, and technology education for students from 9th through 12th grade.

- Gifts of computers to educational institutions—recipients include the Mon Valley Education Consortium; local schools in Pittsburgh, Pennsylvania, and Bartlesville, Oklahoma; and the Commonwealth of Pennsylvania Education Department.

- The Energy, Environment, and Economics (Triple E) Seminar—a two-day multidisciplinary seminar covering energy, environment, and economics at the regional, national, and global levels. The program is tailored to provide hands-on activities for classroom teachers at the kindergarten through 6th-grade level.

In addition, NPTO contributes funds and professional staff to the Oklahoma Energy Resources Board. Its purpose is to educate Oklahomans about the petroleum industry. The board developed two elementary school courses that explain how fossil fuels are formed and produced, and how they enhance our lives. Almost 600 teachers have completed the training course, reaching more than 14,000 students in Oklahoma.

9 Resource Projections

Resource projections are presented in the following tables**:**

Table 1. FY 2002 Laboratory Staff Composition (as of 6/30/02)

FY 2002 Laboratory Staff Composition (Number of Employees)										
	Ph.D.		MS		BS		Other		TOTAL	
	Federal	Contractor Support	Federal	Contractor Support	Federal	Contractor Support	Federal	Contractor Support	Federal	Contractor Support
Professional	3	0	17	28	32	47	11	36	63	111
Scientists	59	16	33	15	29	12	0	3	121	46
Engineers	46	7	94	19	64	42	4	4	208	72
Administrative	2	0	36	1	38	9	42	28	118	38
Technicians	0	0	0	8	4	35	57	152	61	195
All Others	0	0	1	0	3	7	18	99	22	106
Total	**110**	**23**	**181**	**71**	**170**	**152**	**132**	**322**	**593**	**568**

Significant Federal Statistics:

- 32 percent of Scientists and Engineers have Ph.D. degrees.
- 71 percent of Scientists and Engineers have either M.S. or Ph.D. degrees.
- 49 percent of employees have either M.S. or Ph.D. degrees.
- Includes Morgantown, Pittsburgh, and Tulsa sites.

Table 2. NETL New Hires in FY 2002 by Grade Level (as of 6/30/02)

New Hires in FY 2002 by Grade (Number of Employees)											
	White		Black		Hispanic		Asian		Native American		
Grades	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Total
3-7	2	4	1	2	0	0	0	0	0	0	9
8-9	0	1	0	0	0	0	0	0	0	0	1
10	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	1	0	0	0	2
12	1	1	0	1	0	0	1	0	0	0	4
13	5	2	0	0	0	1	0	0	0	0	8
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
SES	0	0	0	0	0	0	0	0	0	0	0
Total	**9**	**8**	**1**	**3**	**0**	**1**	**2**	**0**	**0**	**0**	**24**

Significant Statistics:

- 63 percent of FY 2002 new hires were minorities and women.

Table 3. FY 2002 Composition of NETL Federal Workforce by Grade Level (as of 6/30/02)

FY 2002 Grade Composition of NETL Federal Workforce (Number of Employees)											
	White		Black		Asian		Hispanic		Native American		
Grades	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Total
1-4	4	2	3	3	0	0	0	1	0	0	13
5-7	5	21	1	2	0	0	1	0	0	0	30
8-9	7	15	0	0	0	1	0	0	0	0	23
10	7	1	0	1	0	0	0	0	0	0	9
11	38	19	3	1	1	0	0	0	0	0	62
12	53	33	1	2	2	0	0	1	0	0	92
13	112	34	4	1	12	0	1	1	1	0	166
14	80	13	0	1	10	2	1	1	1	0	109
15	62	6	2	0	4	1	1	1	1	0	78
EJ-V	3	0	0	0	0	0	0	0	0	0	3
SES	6	2	0	0	0	0	0	0	0	0	8
Total	**377**	**146**	**14**	**11**	**29**	**4**	**4**	**5**	**3**	**0**	**593**

Significant Statistics:

- Percentage of women and minorities in the NETL workforce has grown from 30 percent in FY 97 to 36 percent in FY 02 (as of 6/30/02).

- Includes Morgantown, Pittsburgh, and Tulsa sites.

Table 4. Laboratory Personnel Summary (as of 6/30/02)

Laboratory Personnel Summary (Personnel in FTEs)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
Total Federal Employees[1]	574	574	574	574	574	574
Support Contractor Employees						
Onsite	517	517	517	517	517	517
Offsite	89	99	109	109	109	109
Total Support Contractor Employees	606	616	626	626	626	626
Total Research Associates[2]	68	70	70	70	70	70
Total NETL Employees	**1,248**	**1,260**	**1,270**	**1,270**	**1,270**	**1,270**

[1] Includes Projected Work for Others/DOE Reimbursable of 21 FTEs.

[2] Does not include summer intern positions under ORISE or HBCU or other minority institutions.

Table 5. Laboratory Space Distribution (as of 6/30/02)

Laboratory Space Distribution (Square Feet)									
Location	**Type**	**Number**	**Gross**	**Net Useable**	**Common Area**	**Public and Meeting**	**Office Area**	**Lab Area**	**High-Bay Area**
Morgantown	Buildings	39	323,714	298,819	147,292	26,880	54,667	20,605	49,375
	Trailers	18	39,555	36,503	5,583	7,005	23,534	0	381
Pittsburgh	Buildings	32	473,501	415,922	155,343	48,954	105,575	70,681	35,369
	Trailers	3	2,090	1,945	191	217	1,075	462	0
Subtotal DOE-Owned		**92**	**838,860**	**753,189**	**308,409**	**83,056**	**184,851**	**91,748**	**85,125**
Tulsa[1]	Buildings	1	24,600	24,600	12,200	5,720	6,680	0	0
Total NETL		**93**	**863,460**	**777,789**	**320,609**	**88,776**	**191,531**	**91,748**	**85,125**

[1] Leased facilities.

Table 6. Replacement Plant Value[1] (as of 6/30/02)

Replacement Plant Value ($)				
Location	**Buildings**	**Other Structures and Facilities**	**Trailers**	**TOTAL**
Pittsburgh	226,246,229	13,101,400	218,049	239,565,678
Morgantown	184,508,415	22,785,000	8,444,365	215,737,780
Total	**410,754,644**	**35,886,400**	**8,662,414**	**455,303,458**

[1] Leased facilities located in Tulsa, Oklahoma, not included.

Table 7. GPP/Construction Projects ($ in Millions) (as of 6/30/02)

GPP/Construction Projects ($ in Millions)							
	FY 02	**FY 03**	**FY 04**	**FY 05**	**FY 06**	**FY 07**	**FY 08**
General GPP Projects	2,000	2,000	2,000	6,000	6,000	6,000	6,000
New Building Support Projects	9,500	3,000	10,000	3,000	11,000	3,000	2,000
New Building Construction	1,500	8,000	18,000	8,000	0	0	0
Total GPP and Construction Projects	**13,000**	**13,000**	**30,000**	**17,000**	**17,000**	**9,000**	**8,000**

Table 8. Laboratory Funding Summary ($ in Millions) (as of 6/30/02)

Laboratory Funding ($ in Millions—Budget Authority)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
DOE Operating	700.7	729.5	748.6	742.9	759.4	786.1
GPP Construction Projects	11.5	5.0	12.0	9.0	17.0	9.0
New Building Construction	1.5	8.0	18.0	8.0	0	0
Funds Transferred to Other National Labs	48.5	45.0	45.0	45.0	45.0	45.0
Total DOE	**762.2**	**787.5**	**823.6**	**804.9**	**821.4**	**840.1**
Work for Others	23.1	23.5	23.5	23.5	23.5	23.5
Total Funding	**785.3**	**811.0**	**847.1**	**828.4**	**844.9**	**863.6**

Table 9. Funding for Fossil Energy ($ in Millions) (as of 6/30/02)

Funding by Secretarial Office ($ in Millions—Budget Authority)	FY 2002[1]	FY 2003[2]	FY 2004	FY 2005	FY 2006	FY 2007
Assistant Secretary for Fossil Energy (FE)						
Operating	560.3	587.5	581.0	608.0	621.0	644.0
GPP Construction Projects	11.5	5.0	12.0	9.0	17.0	9.0
New Building Construction	1.5	8.0	18.0	8.0	0	0
Funds Transferred to Other National Labs	48.0	45.0	45.0	45.0	45.0	45.0
Total FE R&D	**621.3**	**645.5**	**656.0**	**670.0**	**683.0**	**698.0**
Clean Coal Technology (CCT)						
Operating	9.2	9.4	36.0	0	0	0
Funds Transferred to Other National Labs	0.5	0.5	0	0	0	0
Total CCT	**9.7**	**9.9**	**36.0**	**0**	**0**	**0**
Total FE	**631.0**	**655.4**	**692.0**	**670.0**	**683.0**	**698.0**

[1] FE based on FY 02 appropriations plus current-year adjustments.

[2] FY 03 funding levels based on House marks. Other outyear estimates are based on projected planning levels.

Table 10. Funding by Secretarial Officer ($ in Millions) (as of 6/30/02)

Funding by Secretarial Officer ($ in Millions—Budget Authority)						
Department of Energy	**FY 2002**[1]	**FY 2003**[2]	**FY 2004**	**FY 2005**	**FY 2006**	**FY 2007**
Assistant Secretary for Fossil Energy (FE)						
Operating **Total FE**	631.0	655.4	692.0	670.0	683.0	698.0
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)						
Operating **Total EE**	61.8	64.4	63.4	66.5	69.8	73.3
Assistant Secretary for Environmental Management (EM)						
Operating **Total EM**	63.0	60.0	60.0	60.0	60.0	60.0
Administrator for National Nuclear Security Administration (NA)						
Operating **Total NA**	1.7	0.5	0.5	0.5	0.5	0.5
Office of Nuclear Energy, Science, and Technology (NE)						
Operating **Total NE**	0.2	0.2	0.2	0.2	0.2	0.2
Office of Management, Budget, and Evaluation (ME)						
Operating **Total ME**	4.5	7.0	7.5	7.7	7.9	8.1
Total DOE	**762.2**	**787.5**	**823.6**	**804.9**	**821.4**	**840.1**
Work for Others (Non-DOE)	23.1	23.5	23.5	23.5	23.5	23.5
Total Funding	**785.3**	**811.0**	**847.1**	**828.4**	**844.9**	**863.6**

[1] FE based on FY 02 appropriations plus current-year adjustments. Other fund sources based on approved funding program (Fin Plan).

[2] FY 03 funding levels based on House marks for FE. Other estimates are based on projected planning levels.

Table 11. Work for Others—Funding Obligations ($ in Millions) (as of 6/30/02)

Work for Others—Funding Obligations ($ in Millions)						
	FY 2002	**FY 2003**	**FY 2004**	**FY 2005**	**FY 2006**	**FY 2007**
Work for Others—Federal Agencies						
Department of Defense	2.0	7.9	7.9	7.9	7.9	7.9
Environmental Projection Agency	6.0	6.0	6.0	6.0	6.0	6.0
Other Federal Agencies	15.0	9.1	9.1	9.1	9.1	9.1
Total Federal Agencies	**23.0**	**23.0**	**23.0**	**23.0**	**23.0**	**23.0**
Work for Others—Non-Federal Agencies	0.1	0.5	0.5	0.5	0.5	0.5
Total Work for Others	**23.1**	**23.5**	**23.5**	**23.5**	**23.5**	**23.5**

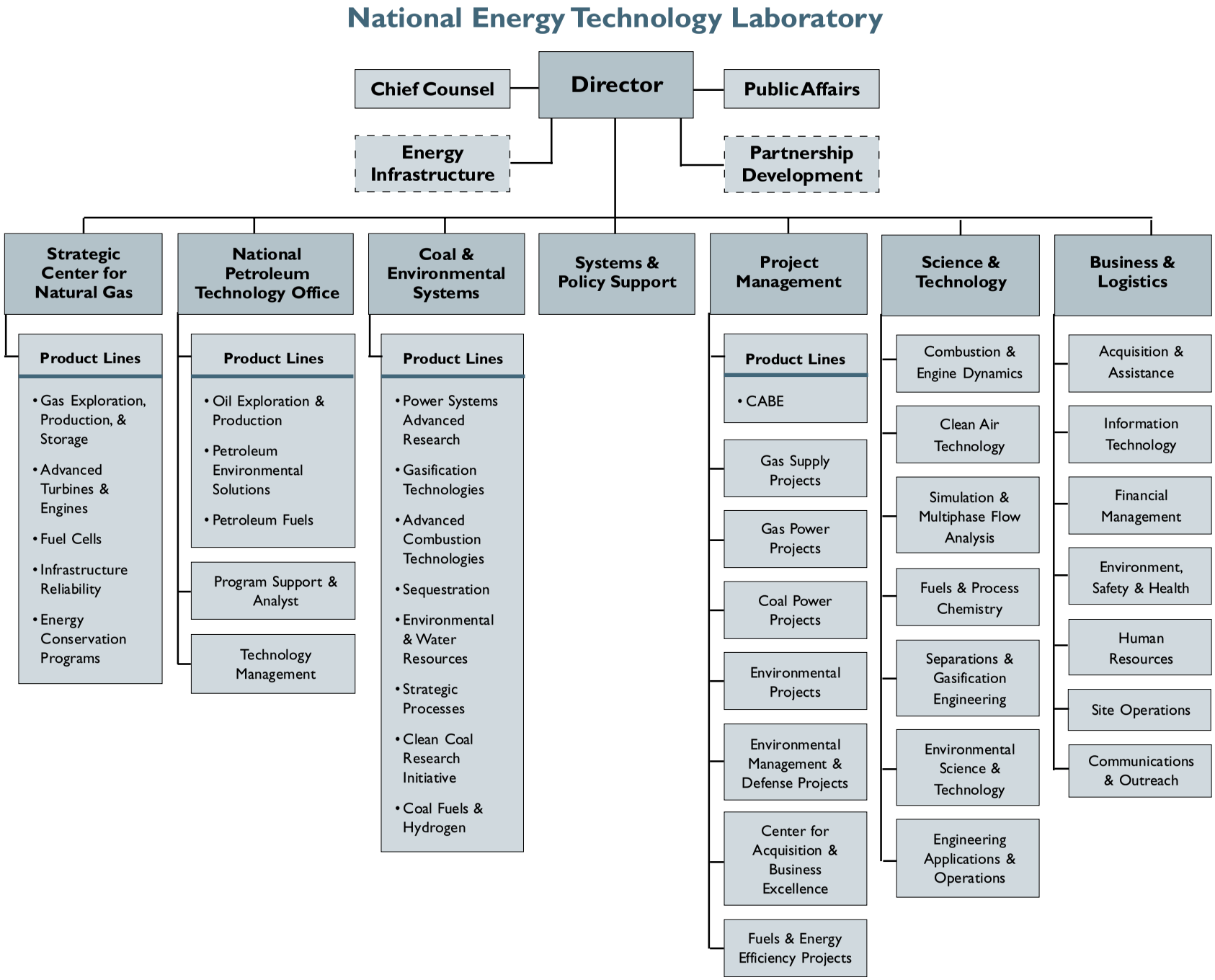


Figure 1. NETL Organization Chart

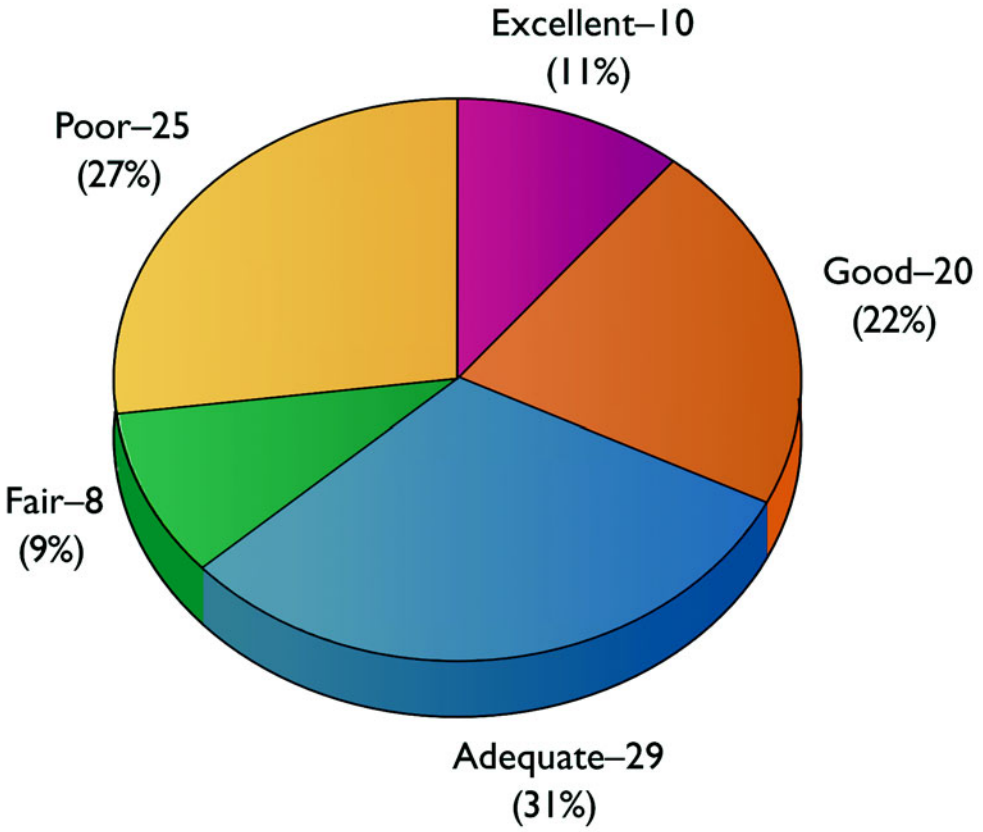


Figure 2. Condition of NETL Facilities as a Percentage of Total Number of Buildings

10 Abbreviations and Acronyms

AACE	Association for the Advancement of Cost Engineering
ACE	applied cost engineering
ANL	Argonne National Laboratory
ASTD	accelerated site technology deployment
ATS	advanced turbine systems
bbl	barrel
BNL	Brookhaven National Laboratory
BS	Bachelor of Science
Btu	British thermal unit
CAA	Clean Air Act
CABE	Center for Acquisition and Business Excellence
CCB	coal combustion byproducts
CE	cost engineering
CEG	cost engineering group
CEMP	Comprehensive Energy Management Plan
CFB	circulating fluidized bed
CFC	chlorofluorocarbon
CO	carbon monoxide
CO_2	carbon dioxide
CR	Office of the Chief Financial Officer
CRADA	Cooperative Research and Development Agreement
D&D	deactivation and decommissioning
DNAPL	dense, non-aqueous phase liquid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DP	Office of Defense Programs
ECAS	environmental cost analysis system
EE	Office of Energy Efficiency and Renewable Energy
EEO	equal employment opportunity
EIA	Energy Information Administration
EM	Office of Environmental Management
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ES&H	environment, safety, and health
F	degrees Fahrenheit
FIMS	Facilities Information Management System
F-T	Fischer-Tropsch
FE	Office of Fossil Energy
FEMP	Federal Energy Management Program
FUSRAP	Formerly Utilized Site Remedial Action Program
FTE	full-time equivalent
FY	fiscal year
GDP	gross domestic product
GHG	greenhouse gas
GOGO	Government-owned, Government-operated
GPE	general plant equipment
GPP	general plant projects
Gt	gigaton (one billion metric tons)
GTI	Gas Technology Institute
GTL	gas-to-liquids
GW	gigawatt (one billion watts)
H_2SO_4	sulfuric acid
HCl	hydrochloric acid
HF	hydrofluoric acid
Hg	mercury
HIPPS	high-performance power system
HQ	headquarters
hr	hour
IA	Office of International Affairs
IFC	International Fuel Cells
IGCC	integrated gasification combined cycle
INEEL	Idaho National Engineering and Environmental Laboratory
IPR	Independent Project Reviews
ISM	integrated safety management
ISO	International Organization for Standardization
IT	information technology
k	thousand

kW	kilowatt
kWh	kilowatt-hour
lb	pound
LCAM	Life-Cycle Asset Management
LEBS	low-emission boiler system
LLMW	low-level mixed waste
LMPC	Labor Management Partnership Council
LNB	low-NO_x burner
LSDDP	Large-Scale Demonstration and Deployment Program
M&O	management and operating
MA	Office of Management and Administration
MARS	Management Analysis Reporting System
Mcf	million cubic feet
MCFC	molten carbonate fuel cell
MS	Master of Science
MW	megawatt
MWe	megawatt electrical
NASA	National Aeronautics and Space Administration
NE	Office of Nuclear Energy, Science, and Technology
NEMS	National Energy Modeling System
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NN	Office of Nonproliferation and National Security
NNSA	National Nuclear Security Administration
NO	nitric oxide
NO_X	nitrogen oxides
NPC	National Petroleum Council
NPTO	National Petroleum Technology Office
NREL	National Renewable Energy Laboratory
NSPS	new source performance standards
NTS	Nevada Test Site
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
PAFC	phosphoric acid fuel cell
PCAST	President's Committee of Advisors on Science and Technology
PFBC	pressurized fluidized-bed combustion
PGNAA	prompt gamma neutron activation analysis
Ph.D.	Doctor of Philosophy
$PM_{2.5}$	particulate matter smaller than 2.5 microns
ppm	parts per million
PSC	Pittsburgh Supercomputing Center
PSDF	Power Systems Development Facility
R&D	research and development
RAM	reliability, availability, and maintainability
RD&D	research, development, and demonstration
RFI	Rocky Flats D&D Initiative
SC	Office of Science
SCEP	Student Career Employment Program
SCNG	Strategic Center for Natural Gas
SCR	selective catalytic reduction
SECA	Solid State Energy Conversion Alliance
SES	senior executive service
SOFC	solid oxide fuel cell
SOP	Site Operations Division
SO_2	sulfur dioxide
SO_X	oxides of sulfur
SRS	Savannah River Site
Tcf	trillion cubic feet
TRU	transuranic
U.S.	United States
USAID	United States Agency for International Development
USGS	United States Geological Survey
VOC	volatile organic compounds
VE	value engineering
WIDE	well injection depth extraction
WFO	work for others
WIPP	Waste Isolation Pilot Plant
WVU	West Virginia University
y	year

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